FIRST STEPS IN COAL MINING

FOR USE IN SUPPLEMENTARY AND CONTINUATION CLASSES

BY

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PREFACE

In many mining districts no provision is made for the instruction of the miner in the subjects of his calling or in the rules framed for his safety. Classes for the preparation of candidates for the Mine Managers' Examinations are indeed held, but these, being unsuitable for the needs of the ordinary worker, are attended only by those whose ambition prompts them to seek to better their position. Happily, in accordance with modern ideas, a better system seems likely to be generally inaugurated, and under it all boys entering a mine will receive some training in the principles underlying their work, and such instruction as will tend to reduce the deplorable number of fatal and serious non-fatal accidents.

In the present book, intended specially for boys from twelve to sixteen years of age, the writer, while, it is hoped, dealing fully with such matters as directly concern the worker, has not confined himself to these, believing that to give the pupil a little insight into some of the difficulties connected with mining could not but increase his interest and broaden his outlook. As far as management is concerned, care has been taken not to recommend one practice as being better than another. It is hoped that the book will be found suitable as a "reader", the teacher by oral questioning and by demonstrations satisfying himself that the matter is thoroughly understood.

The practical work of a class should be done very thoroughly. Thus, in the case of safety lamps, the pupils should take the lamp to "pieces" and fix it up again as often as is necessary,

and he should learn thoroughly the uses of the different parts. He should also learn how to clean the lamp and how to test for gas. Again, in dealing with blasting, much valuable work can be done.

Many things may be made by the pupils, such as plumb-bobs, shaft fittings, &c., and pupils are delighted to engage in such work as taking "the sights". In teaching Geology, "specimens" should be produced as often as is necessary, and little outdoor excursions should be made occasionally. It should not be forgotten that the pupil may find this subject a source of much interest in after life.

[1] A copy or copies of the Coal Mines Regulation Act, Special Rules, and Explosives Orders, as well as a copy of the District Mine Inspector's Report, should be in every school or class. Some references to the General Rules are made in the text. The General and Special Rules should be taken together and studied with the matters to which they refer, not read straight through.

In conclusion, the writer has to thank the Controller of His Majesty's Stationery Office for permission to use figs 1, 2, 3, while to A. Sopwith, Esq., he is greatly indebted for kindly giving him leave to reproduce a few of the excellent photographs taken by him, figs. 93, 94, 101, 124, 136, and 167. A few illustrations have been taken, by permission, from the Gresham Publishing Co.'s excellent book, *Practical Coal Mining*, while the bulk of the other illustrations are the property of the publishers, to whom the writer is much indebted for their use.

A. F.

[1] A copy of the Coal Mines Act, 1887, and of each subsequent Act, Explosives Orders, &c., may be obtained from the Government publishers, through any bookseller, for a few pence. An abstract of the Act and copy of the Special Rules must be posted in a conspicuous place at or near the mine, and a printed copy of abstract and Special Rules supplied gratis to each person employed who applies for same at the pay office.

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CHAPTER I

INTRODUCTORY

To the Young Reader—Uses, Importance, and Distribution of Coal—First Use of Coal—Condition of Mining Population in Past Times

1. **To the Young Reader.**—In this little book there will be found explained what coal is, how it comes to be buried in the ground, how it is dug, and how it is brought to the surface, together with many other things necessary to make the whole matter very plain.

The object of the book is to enable the young pitman to understand his surroundings in the mine, and the nature of all colliery operations. Formerly boys beginning work underground were not taught anything in school or class concerning these matters, and had to pick up their information in the mine itself. That was very hard on the boys, and it had the further great disadvantages that many things in the mine could not possibly be understood, and others could only be learnt in a "rule of thumb" way.

The modern method is, then, the better. Under it our training is divided into two parts: the *practical part*, received in the mine itself, and what is *essential for the efficient performance of the practical part*—

sometimes termed the *theoretical part*—received from books such as this, and in school or class.

In past times boys were left to learn what they could in the mine, because people had not recognized the value of that education (generally called *technical education*) which enables a person to understand the reason of things, and therefore to think correctly about things and to apply his energies to the best advantage. But its advantages are known fully to the people of the present day; and not only are means provided for the technical education of all classes of workmen requiring special skill or care in the exercise of their vocation, but each individual *is expected* to make himself as proficient as possible in whatever occupation he may follow. If he does not do that, then his value as a workman is less, and he fails in his duty both to himself and his country.

The young reader should keep this in mind as the chief reason for studying the subject; though learning the *Principles of Mining* (or general fundamental truths) is really a pleasure, they are so attractive in themselves, and in many cases of such a general nature as to appeal to everyone, whether connected with mining or not.

Then when we have completed our studies, so far at any rate as book and class are concerned, what an amount of interest is imparted to our labours and surroundings in the mine, as we constantly seek to apply our knowledge! This, obviously, could never be the case if we knew nothing of the causes of things, and were content to perform our tasks without intelligence and without thought, like mere human machines.

The young reader now understanding a little as to the object of his studies, something may be said concerning the uses of coal, and the other subjects enumerated at the beginning of the chapter.

2. **Uses of Coal.**—The outstanding use of coal is, of course, as a *fuel*, or means of producing heat. The purposes for which heat, derived from the burning of coal, is required are many and varied, and need not be mentioned here. But we can realize the importance of coal as a fuel if we try to picture to ourselves what our homes would be like without their cheerful fires. If we felt cold and hungry, from what source would we obtain the heat necessary to warm ourselves, and by what means would our mothers be able to cook our food. Again, if there were no coal, how could those great engines which we see daily rushing through the country move themselves, not to speak of drawing trains of wagons—how, indeed, could the engines themselves be built.

Plainly, then, coal is necessary as a substance that may be burnt and produce heat; but while that is so it must not be forgotten that it has other uses. Thus from coal *coal gas* is obtained, and from the *coal tar* produced in the manufacture of the coal gas different substances are made, including many brilliant *dyes*.

3. **Importance of Coal.**—It is easy, then, from what has been said, to understand the importance of a large supply of coal to a great naval power and manufacturing nation like our own. Fortunately the amount of this precious substance stored up in our little island is very great. But the amount produced, or the *output* as it is called, is also very great. No fewer than 260 million tons of coal are now raised annually in this country from the bowels of the earth, giving direct employment to nearly one million persons. A few years ago people became alarmed at the rapid diminution of our coal supplies, and Parliament appointed a Royal Commission to enquire into the extent of these. This Commission completed its labours in due course, and happily there is no reason to believe

that our stores of coal will be exhausted for hundreds of years to come Old districts will be worked out, but new ones will be tapped, and deeper seams opened up. At the same time it must be borne in mind that our supplies are not inexhaustible, and that some day our descendants will be faced with the problem of having to find a substitute for coal.

Britain was formerly the largest coal-producing country in the world, but now ranks second to the United States of America. Next to Britain comes Germany. The world's annual output of coal is now over 1100 million metric tons

4. **Distribution of Coal.**—By this is meant the occurrence of coal in different parts of the world. It need only be said here that coal is found in greater or smaller amount in most countries. Countries which have either no coal or an amount too small for their needs are supplied from others which have abundance. Thus a large part of the output of Britain is carried in ships to foreign parts, giving employment to more men and adding to the wealth of the country. But of course the coal sold in this way is helping to deplete our stores and can never be replaced.

In connection with the occurrence of coal we must notice that although a country has abundant supplies, yet these are not spread over the whole land, but are found in patches or "fields". The reason for this will appear in chap. xvi.

5. **First Use of Coal.**—People in this country are so accustomed to the presence of coal that they are in danger of thinking it must have been largely used in all times. Such an assumption would, however, be wrong. It was only after the application of steam power to machinery that coal began to be used in large quantities. Previous to that there was no need for

very large supplies, and, even if there had been, it was impossible to obtain them without steam; because, for one thing (chap. xl) the mines had to be kept free from water. The work of James Watt on the steam engine enabled this to be done; and, with the extension of steam power to all sorts of purposes, the demand for coal increased rapidly and has continued to grow ever since.

The date when coal first began to be employed as fuel is uncertain. In the earliest times wood was the substance generally used in all countries; and where that was scarce, as in some parts of Egypt and India, other material had to be substituted.

Britain, it is believed, was the first European country to use coal to any considerable extent. Some people think it was employed by the ancient Britons, and that the Romans learnt about it from them; but however that may be, coal, it is stated, was in use as early as 852. Between 1210 and 1219 a coal pit at Preston, Haddington, was granted to the monks at Newbattle, while in 1239 Henry III granted to the freemen of Newcastle-on-Tyne a licence to dig coal.

In London, coal was for a long time known as *sea coal*, because imported by sea. It began to be employed here about the end of the thirteenth century, but its use was regarded as injurious to health. In 1306 Parliament petitioned the King to prohibit its employment, and this was accordingly done. Wood, however, was very costly, and coal soon came into general use.

The following quaint reference to the use of coal in Scotland in the early fifteenth century is made by Æneas Sylvius, an Italian, who visited Scotland and wrote an account of his travels. He says: "In this country I saw the poor, who begged at the church doors, depart with joy in their faces on receiving stones as alms. This stone, whether by reason of sulphurous or

some fatter matter which it contains, is burned instead of wood, of which the country is destitute."[1]

6. **Condition of Mining Population in Past Times.**—The young reader has already learnt something of the great advance that has taken place in the education of miners, and similar changes have occurred in other respects. In the early days of the coal-mining industry the colliers were virtually slaves or serfs, not being allowed to remove from the places of their birth. In later times they were given their freedom, but their lot cannot be

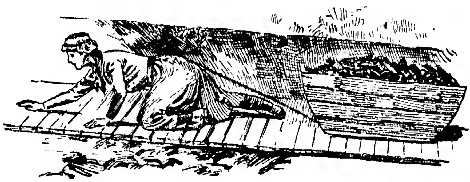


Fig 1 -Girl "Hurrying" Coal with a Strap and Chain

said to have been much improved. The women and children as well as the men worked in the mines; and, so long were their hours of labour, they scarcely ever saw the light of the sun. Besides the long hours, the mines were badly ventilated and the roads often covered with water. The boys and girls were frequently ill-treated and set such hard and cruel tasks as sometimes to result in deformity. Figs. 1–3 illustrate the kind of work performed by the poor women and children. A common age for boys and girls to begin work underground was seven and eight years, but instances are known where children even three years of age were taken into the mine and made to hold candles while their fathers were at work. Under these conditions no

attention could be paid to education, and boys and girls grew up quite ignorant of everything they should know. No wonder, then, the mining population was wild and superstitious, and mining considered one of the most inferior of occupations.

Happily this state of affairs has long ceased to exist,

Fig. 2.—Women Carrying Coals up Ladders

and may be regarded as belonging to the "dark ages" of the industry. Mines are now well ventilated, and with the modern machinery at command there is no need for the primitive methods of removing the coal adopted in early times. Moreover, the hours of labour are comparatively short; and with the improved conditions of work, better pay, better education, and long

intervals for rest and play, the young pitman of the present day will see that he has been born in happier and better times than the mining youths of the past.

In 1842 an Act of Parliament was passed prohibiting the employment of women and girls underground, and raising the entrance age for boys to ten years,

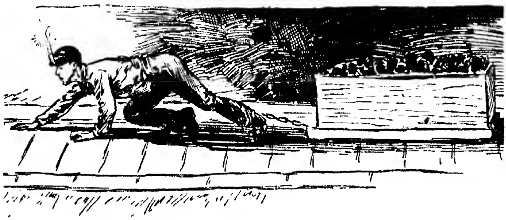


Fig 3.—Boy Dragging Coal Tub, with Candle-holder, Skull-cap, and Girdle

though boys under ten already at work in the mine were allowed to remain. In later years the limiting age for boys was raised to twelve, and now no boy can begin work in a mine until he is thirteen years of age, and then only under certain conditions.

CHAPTER II

THE INTERIOR OF THE EARTH

Shape and Size of the Earth—Crust of the Earth—Geology and Geologists—Movements of Rocks.

In this and following lesson we shall have to enquire as to the nature of the interior or inside of the earth.

7. **The Shape and Size of the Earth.**—In regard to the shape of the earth we must note that it is round, and

not flat as was formerly believed to be the case. Concerning the size, it is very important to realize that the earth is an extremely large body. We say that its diameter is about 8000 miles. This means that if we could bore a hole right through the earth, and then measure the length of the hole, we should find it to be about 8000 miles. Halfway through the hole, or 4000 miles from either end, would be the centre of the earth So the distance from the surface to the centre of the earth is about 4000 miles.

8. **The Crust of the Earth.**—Now no person knows anything as to the nature of the earth to a greater depth than about 20 miles. Twenty miles is not much in four thousand. It is a great deal less in proportion than is the thickness of the skin of an orange to half the orange. Yet the statement is quite true. Man knows something about the inside of the earth down to a point about 20 miles below the surface, but of what is underneath that he can only guess. The part of which he has learnt something, it will be seen, forms a mere shell or rind. It is called the *crust of the earth.*

Now, although 20 miles is a small fraction of the distance to the centre of the earth, it is a great tribute to man's powers of observation and reasoning that his knowledge of the interior should extend so far. He is only able to see the rocks to depths of about one mile, yet it is from what comes under his personal observation that he can tell what lies below.

9. **Geology and Geologists.**—The earth is a very much older body than people are apt to think. It is known to have been in existence for millions of years, and to have undergone great changes. It has therefore a 'story" or history, and the science or branch of knowledge that deals with that history is called *geology.* Men who are skilled in geology are known as *geologists.*

It is geologists, then, who find out things concerning the history of the earth. Rocks, of course, occur everywhere on the surface of the earth (some in huge irregular masses, and some in regular beds or layers), passing

Fig. 4.—The Great Cañon, Colorado

down into the earth and under the sea—the sea occupying hollows in the land. Geologists examine the rocks wherever they are to be seen, visiting such places as quarries, railway cuttings, sea cliffs, ravines, wells, the shafts of deep mines, &c., and noting the appearance of the beds, their nature, arrangement, &c.

Fig. 4 shows how geologists are enabled to become acquainted with the rocks for considerable depths. The Great Cañon of Colorado is at places over 6000 ft. deep.

Geologists also obtain information as to the rocks from holes bored deep in the ground, and from the material discharged from volcanoes.

10. **Movements of Rocks.**—Now, by examining the rocks in the places named, and, as has been indicated, not merely in this country but in all countries, geologists became aware that the beds do not usually lie evenly, one above the other, like the coats of an onion, but, having been upheaved, are, in most places, bent, folded, and broken, often in the most remarkable ways (figs. 23–6).

The cause of these upheavals, and of the other movements of the rocks in the earth's crust, will be explained in a future lesson, but as a result of them, and also of the wearing away of the earth's surface, beds are found which, if arranged in a vertical pile, one bed regularly on the top of another like the coats of an onion, would form a column about 20 miles thick. Hence it is that man is able to tell something about the interior of the earth to as great a depth as 20 miles, little as that is compared to the total distance to the earth's centre.

But we must not think that it would do to arrange the rocks in the pile in any order. Of course no matter what beds might be placed above other beds the total thickness would be about 20 miles; but, as will be seen further on, the making of the beds of rock forming the earth's crust has gone on at all times, some being produced during one period of time and some during another, and to have them in their proper position in the pile, then the older or first-formed beds ought to be at the bottom, the next oldest on the top of these, and so on, up to the newest or most recently formed rocks at the surface. Fortunately geologists have learnt

to tell the ages of the different beds of rocks compared one with another (though they cannot tell their actual ages), and so are able to say which beds would be 20 miles down and which at other parts of the pile, just as if all the beds were lying in the earth's crust according to the time they were formed, and they could see them right from the top to the bottom. How it is possible for geologists to do this we shall learn in chap. xv

CHAPTER III

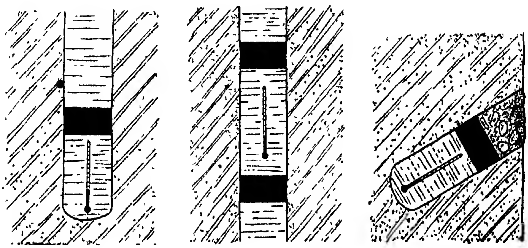
THE INTERIOR OF THE EARTH—(*Continued*)

Internal Temperature of the Earth—State of the Interior—Liquid or Solid—Proofs of the Internal Heat of the Earth—Parts of the Interior may be Liquid.

11. **Internal Temperature of the Earth.**—As the first part of the present lesson we must see why the part of the earth with which man is acquainted is called the "crust of the earth". People do not usually speak of the "crust" of anything unless it has a hard outer and a soft inner part. Well, that is what was at one time believed about the earth—that it had a hard outer part (the crust) and a soft inner part (the part inside the crust). What led to this belief was the high temperature of the earth's interior.

It is certain that the earth is very hot inside. This is not apparent at the surface, because the rocks there are at the same temperature as the surrounding air. Nor would we notice any difference if we were to dig a few feet down into the ground. But if we dug far enough down a difference would be perceived. It is found that the farther we descend into the earth the hotter it becomes.

At from about 60 to 80 ft. below the surface of the earth in temperate regions a zone or belt of rocks is reached, the temperature of which is alway the same. This is termed the "zone of constant temperature". From the surface down to this zone the temperature varies according to the season of the year. In cold weather, therefore, the rocks forming this part will be at a lower temperature than in warm weather. This is shown



a b c

Fig 5.—Thermometers in Hollows or Water Chambers in Rocks

a, At bottom of borehole; *b*, midway in borehole; *c*, in cavity at side of shaft. The black bands represent plugs, which prevent the circulation of water.

during times of severe frost by the ground becoming very hard and difficult to dig into.

Below the zone of constant temperature the rocks, as already mentioned, get hotter with the depth. By taking readings of the thermometer at different depths (fig. 5) geologists have ascertained the amount by which the temperature increases for a given distance down into the earth. It is not the same everywhere, but may be taken to be roughly about 1° F. for every 60 ft. of descent.

When finding the temperature of the rocks geologists use self-registering thermometers, which they lower

into boreholes, or embed in cavities in shafts and mines (fig. 5). They can therefore only tell the rate of increase of temperature to depths attained by the deepest mines and boreholes, the deepest borehole up to the present being about 1¼ mile. Whether the temperature continues to rise farther down at the same rate as in the case of mines and boreholes it is impossible to say. If it does, then, indeed, at the depth of a few miles it must be very high. Thus at 2 miles the reading at which water boils (212° F.) would be attained, while at a depth of 40 or 50 miles the heat would be so great as to melt any kind of substance known to us

It will now be easy to understand how the term *crust* of the earth came into use. Owing to the great internal heat of the earth, geologists thought everything a certain distance down must be in a molten state, that the earth, in short, consisted of a *molten inner part or interior*, and a *solid outer part or exterior*. The hard solid outer part being so thin in comparison with the distance to the earth's centre was naturally called the "crust".

12. **Interior of Earth not Liquid.**—But, though the term crust of the earth was based on the idea of a liquid interior, that idea is not now held, and therefore it must be clearly understood that when anyone speaks of the crust of the earth *no liquid interior is implied.* The term "crust of the earth" now simply means *the portion of the exterior of the earth about which man knows something.* Geologists are convinced that the earth was at one time much hotter than it is at present, and that it has been, and is, slowly cooling down; but for certain reasons they do not now think that it is liquid inside. On the contrary, most geologists believe it to be solid throughout.

In § 11 we learnt that if the temperature continued to rise deep down in the earth at the same rate as in the

outer part of the crust (that is, as in deep mines and boreholes) the heat at a depth of 40 or 50 miles would be sufficient to melt any known substance. But the pressure of the rocks also increases with the depth, as the ones farthest down have to bear the weight of those above, and it is thought that this increased pressure might prevent the rocks from melting. When a rock or other solid body melts it requires more room, and if the pressure is so great that it cannot get this room, then,

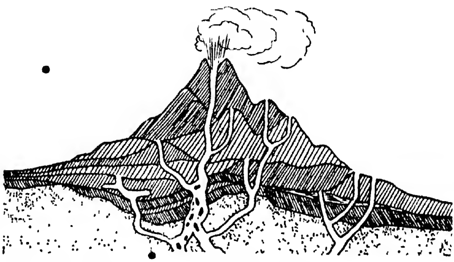


Fig. 6.—Section of an Active Volcano, showing several pipes or vents, and also the beds of lava and ashes which have issued from these pipes

of course, it cannot melt. Also, as was pointed out in § 11, no one knows whether deep down in the earth the temperature does increase at the same rate as in the outer parts of the crust.

13. **Proofs of the Internal Heat of the Earth.**—In addition to the observations by geologists of the temperature in mines and boreholes, there is the evidence afforded by volcanoes that the interior of the earth is very hot. A volcano (fig. 6) has a pipe or channel by which it is connected with the depths of the earth, and up through which are sent steam, hot gases, and molten rock. The materials ejected from volcanoes being so intensely hot,

the place where they come from must also be very hot. Again, hot springs are to be found in many parts of the world, and the water of these springs must have been made warm in the earth.

14. **Parts of the Interior of the Earth may be Liquid.**—In connection with volcanoes it may seem curious that molten rock or lava should be ejected, if it is true (§ 12) that the earth is solid throughout. But when the rocks at any part are upheaved (see § 10 and chap viii), then the pressure at that part will be reduced and the solid matter become liquefied. Then some geologists think (§ 12) that part or parts of the interior of the earth may be liquid.

CHAPTER IV

THE ROCKS FORMING THE CRUST OF THE EARTH

The Term Rock—Different Kinds of Rocks—Rocks to be Studied.

15. **The Term Rock.**—Knowing now what is meant by the "crust of the earth", we may go on and enquire as to the rocks forming it. The first thing to determine is the precise meaning to be attached to the term "rock". As used generally this word simply denotes a mass of hard stone, as, for example, a piece of basalt. No one ever thinks of calling such substances as sand and coal rocks. But geologists look at the matter from a wider point of view. They call anything solid, whether it is loose or compact, which goes to make up the earth's crust, by the name of rock. Thus sand and coal, according to a geologist are rocks.

16. **Different Kinds of Rocks.**—Taking, then, the geolo-

t's idea of the term, let us name some common rocks, it is, rocks which we know to form part of the earth's st. There are *clay, shale, sand, sandstone, chalk, stone, peat, coal*, and very hard rocks such as *nite* and *basalt* (which in some districts is called hinstone", or "whin", this being a common name all similar hard rocks). Then there are such rocks *slate*.

17. **Rocks to be Studied.**—Now to understand about l it is not necessary to consider all the rocks menned in the preceding paragraph. At the same time is not sufficient merely to learn about coal itself. l occurs in the earth's crust in great beds or sheets, led *seams*, covered by beds of shale, sandstone, &c. s. 37, 38), and the question of how the coal comes be buried under these rocks can only be satistorily answered by having regard to the way in ich they have been formed. The rocks, sandstone l shale, then, must first be studied, also a rock called *glomerate*, or "pudding stone" (fig. 29). Next must considered limestone, beds of which are sometimes ociated with coal; and then the formation of coal elf. Then, it will be necessary to enquire how rocks h as whinstone are formed, large masses of this stance being found sometimes to cut up through l seams; while in a final lesson it will be well to see out ironstone and slate, and such other rocks of which s desirable to possess a little knowledge.

But it would not be easy to begin the consideration shale and sandstone at once. If a mason at work lding a house be observed, it will be seen that he uires to have all his materials brought near to him. nilarly, before engaging in the building up of shale l sandstone rocks, so far as that is possible in the ges of a book, we must have the materials of which

they are composed laid down where the work is to be done. But it is necessary for us to go further than the mason. It suffices him as a rule to have the stones, mortar, &c., brought to a place where he can conveniently lay hands on them, without troubling himself as to how they have been brought there or the source whence they have been obtained. But here it is different. Shale and sandstone are composed respectively of mud and sand, and not only must the mud and sand be laid down in the proper place, but we must see where these substances come from and how they are conveyed to the required spot.

It may be said at once that shale and sandstone are formed at the bottom of the sea or of a lake. The mud and sand are obtained from the wearing away of the solid land. They are carried to the sea or lake by rivers, which are also instrumental in the formation of mud and sand. How all this is possible will be seen in the next few chapters.

CHAPTER V

THE WASTING OF THE LAND

Action of Heat and Cold on Rocks—Action of Rain—Running Water and Springs—Stalactites and Stalagmites—Bone Caves.

Nothing appears to us so permanent as the solid land. Whatever else may change, that seems as if it could know no difference. Yet the whole surface of the earth is slowly undergoing alteration. As Tennyson says:

"The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands,
Like clouds they shape themselves and go".

These changes are the result of the action of various agencies, such as heat and cold, rain and frost, &c. How each of these does its work in cutting up or removing the land surfaces must now be considered.

18. **Action of Heat and Cold upon Rocks.**—To study the action of heat and cold, &c., upon rocks we should select some inland cliff or rocky hillside, with a large stream or small river running at its foot. When a bladder filled with air is held in front of a fire we know that it swells out or expands, owing to the effect of the heat on the air. If the bladder is then removed to a cold place it returns to its former size. If heated a second time it once more expands, only to again return to its original size when cooled down. The effect, then, of alternately heating and cooling the bladder is to make it *expand* and *contract*.

Now the same thing happens in the case of the rocks forming any hillside or cliff, but to a much smaller extent. During the daytime the rocks, acted on by the sun expand, while at night, owing to the change of temperature, they contract or shrink to their former dimensions. Solid bodies are less affected by heat than is air, and for this reason the expansion and contraction of the rocks, unlike that of the bladder, is not visible, but it nevertheless takes place and goes on unceasingly, week after week and year after year. In the end the continued strain proves too much for the rocks to withstand, and they crack, or pieces scale off and roll down the sides into heaps, whence they find their way into the stream below.

In regard to the expansion of solid bodies by heat, a metal ball which just passes through a ring at the ordinary temperature will not, when heated, pass through, owing to its expansion; when allowed to cool, the ball contracts to its former size, and can then again be passed

through the ring. More will be learnt in chap. xxvi as to the expansion of bodies by heat. The action of heat and cold on rocks is more marked in hot, dry countries, where the range of temperature is greater than in Britain, and many sandy deserts have been thus formed; yet observation of any rocky surface shows us that the same thing takes place in this country.

19. **Action of Rain.**—Rainwater acts on rocks in different ways. In the form of showers it softens and loosens the particles of the rocks, and also washes them down from higher to lower levels.

20. **Running Water.**—But rainwater has a greater effect on rocks in being the source of runnels or streams. After very heavy or continuous showers great rushes of water take place all over the land. In towns the gutters run full, while in country districts the road surfaces are frequently washed bare. On the hills streamlets are formed, and these carry with them all loose rock material.

> "Down foam the rivulets, red with dashing rains,
> The gathering floods burst o'er the distant plains."
> —*Burns.*

The new surfaces produced by the rushing waters in time give place to others. Thus with every fresh supply of rain the brooks and streams wear their beds or channels wider and wider, the rock material which once filled the space being transported to the river below (see fig. 7). That streams and rivers in wet weather are carrying away large quantities of earth or rock material may be shown by filling a glass with the water and allowing it to stand for a time. A thick sediment gathers in the bottom of the glass.

Rainwater acts on rocks in yet another way. As the drops of rain fall through the air they take up

certain gases, and these assist in the breaking up of the rocks. One of the gases so obtained (a further supply of this gas is obtained by the raindrops from

Fig 7 —Production of a Valley by a Mountain Stream

the decaying vegetable matter in the soil) is *carbonic acid* (chap. xxix), and by the aid of this gas the rain water is able to "eat away" or *dissolve* parts of rocks such as granite and limestone, the latter being almost entirely eaten away. Rock material when dissolved is

invisible and is said to be *in solution.* After being dissolved, the limestone, &c., is carried away by the water, which remains quite clear, and is said to be "carried away in solution". An example of a common substance "in solution" is sugar dissolved in hot water or tea.

Fig. 8 gives an excellent idea of the dissolving action of rainwater on rocks, the cracks in the rocks having become widened out into deep fissures. Large caves

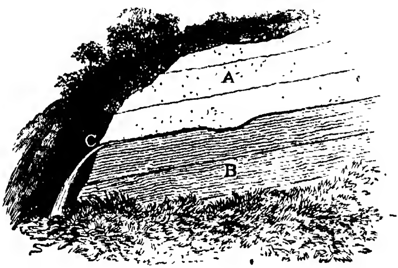


Fig. 10—Section of Hillside

A, Limestone. B, Clay. C, Spring.

are also formed in limestone districts, and in some places underground rivers result from the rain and streams falling down the fissures in the rocks. Fig. 9 shows the effect of rain, frost, &c., on granite rocks.

21. **Springs.**—It is by the dissolving action of water on rocks that *springs* are enabled to perform their work of destruction. Of the water that falls on the land as rain, part reaches the rivers by means of streamlets, &c., in the way just described, part is evaporated back into the air, and part goes to form springs (and then finds its way also to a river). It is the last part with which we are at present con-

Fig. 8.—Summit of Hampsfell (near Grange-over-Sands), showing the action of Rain upon Limestone Rocks

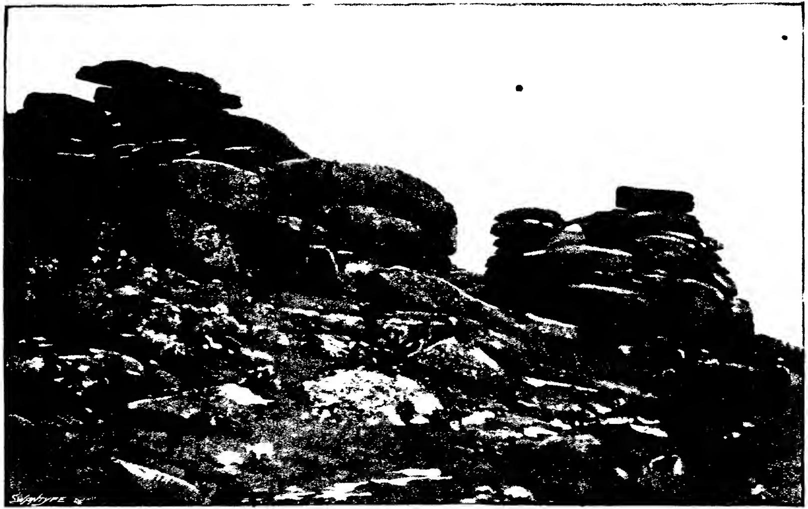


Fig 9 —Pu Tor, Dartmoor an illustration of the "Weathering of Granite

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cerned. After falling on the surface the water sinks down through such rocks as sandstone, chalk, &c., until it meets a bed, such as clay, through which it cannot pass. It then reappears at some other point on the surface in the form of a spring (fig. 10). It is worth noting that the rocks through which water can find its way easily, whether on account of their being porous or containing cracks, are called *pervious*, while those which offer great resistance to its passage are termed *impervious*. Sandstone, chalk, &c., therefore form pervious beds of rocks—clay, whinstone, and slate being impervious. This, it should be observed, accounts for sandy soils being dry and clay soils wet, the former giving free passage to the water, and the latter retaining it.

Fig 11.—Cave with Stalactites and Stalagmites

In its journey through the rocks the water dissolves and carries off rock material in solution. The nature of the spring water depends on the kind of rocks it permeates. In limestone districts, for example, the water is "hard", the hardness being due to the limestone matter dissolved in it. Similarly other springs may contain iron, salt, &c. When the amount of mineral matter dissolved in the water is very great, the term *mineral spring* is used.

The dissolved rock matter contained in spring water may be carried direct to a stream or river, but sometimes it is deposited at the mouth of the spring and can then be seen and examined. In any case springs are powerful agents in the destruction of rocks.

22. **Stalactites and Stalagmites.**—Sometimes dissolved rock matter is deposited in underground caves (fig. 11). This happens in limestone districts. The cave is first hollowed out by the water dissolving and carrying off the rock matter. Afterwards more water laden with rock material in solution arrives at a point above the

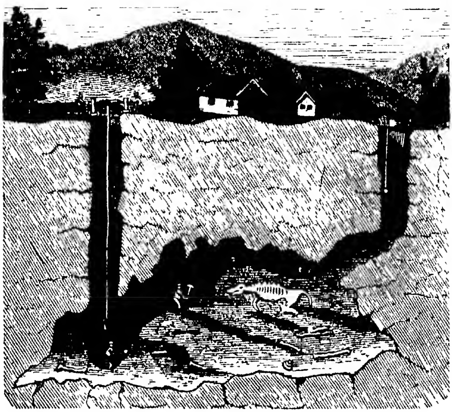

Fig. 12.—Bone Cavern at Wirksworth, in Derbyshire

cave and passes slowly through the fissures in the roof. As the drops hang suspended for a moment they give up some of the dissolved matter, forming what are called *stalactites*. These project downwards from the roof like icicles (fig. 11). The drops of water then splash on to the floor, and more dissolved matter is deposited, forming *stalagmites* (fig. 11). The water continues to drop, running slowly down the stalactites, and always giving up dissolved rock matter. Thus both stalactites and

stalagmites gradually grow larger, and may ultimately meet each other and form pillars.

23. **Bone Caves.**—Sometimes when the stalagmitic floors of caves in limestone regions are broken up, bones of different kinds of animals are found (fig 12). These animals lived in the caves in past ages. When they died their bones became sealed up in the layers of stalagmite and thus preserved. Tools and weapons once used by men are likewise sometimes found, showing that in remote times the caves must also have formed the dwelling places of man.

CHAPTER VI

THE WASTING OF THE LAND—(*Continued*)

Action of Frost on Rocks—Action of Rivers—Formation of River Valleys—Glaciers

24 **Action of Frost on Rocks.**—Frost has a very destructive effect on rocks. This is owing to the fact that water when being converted into ice expands, about 10 c. in. of water becoming 11 c. in. of ice. If, then, the water when freezing is confined in any space or vessel, so that it has no room to expand, a great pressure will be exerted on the walls enclosing the space or sides of the containing vessel. The force developed in this way is well shown by experiments such as that illustrated by fig. 13. Here an iron shell, filled with water, and having the stopper driven tightly in, has been split by the expansive force of the freezing water, while the stopper of a similar shell is seen to have been forced out, a cylinder of ice projecting from the hole. Similar experiments may be carried out during

frosty weather with bottles filled with water and tightly corked.

Now the force that is capable of splitting an iron shell can be well believed to have a very destructive effect on rocks. The water finds its way into natural fissures or openings in the rocks, or into the breaks produced by alternations of heat and cold, or other causes. As it freezes it forces the sides of these openings more widely apart.

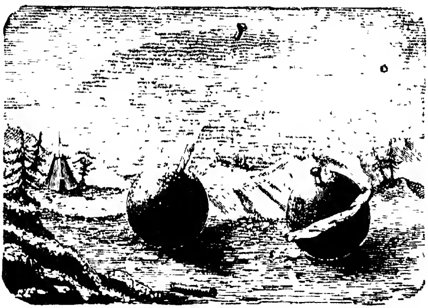

Fig. 13 Effect of Frost on Iron Shells filled with Water

This is repeated again and again, until at last pieces of rock are forced off and roll down the side of the hill to join the heap at the bottom, or fall at once into the river.

25. **Action of Rivers.**—The pieces of rock broken off by the agency of heat and cold, frost, &c., as has been pointed out, may at first accumulate on the side, or at the foot of the cliff, but in the end they find their way into the river. Once there they become subject to the action of the running water, and are gradually reduced to sand and gravel.

On entering a body of water it is found to have a "lifting-up" or supporting tendency, so that substances would actually seem to weigh less in water than out of it. Such indeed is the case. Owing to its lifting-up or supporting power—called *buoyancy*—water has the effect of reducing the weight of bodies immersed in it, and if, say, a piece of stone be weighed first out of water and then when immersed in it (fig. 14), the weight in water will be found to be considerably less. It is therefore easy to understand that water in motion is capable of moving larger pieces of rock than would be the case if they weighed the same as on land, and this especially in times of flood.

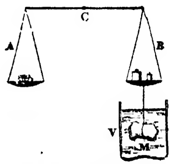

Fig 14.—Weighing a Solid Body in Water

On entering the water, then, the fragments of stone from the hillside, if small enough, are carried forward by the current. As they are swept onwards they knock against each other and against large boulders in the bed of the stream. Their sharp edges and corners are broken off, and the whole mass rounded and smoothed and gradually worn down to the finest particles. Examination of the rock material in the bed of any river or large stream shows this to be the case. At all points are to be found rocks, both large and small, worn quite smooth and more or less round (fig. 17), while here and there are patches of sand and gravel which have been cast up by the running water, and much of which will probably be removed when the river is again in flood.

The pieces of rock which are at first too large for the water to carry away are gradually reduced to the proper size by the smaller pieces coming in contact with them. Nor does the river bed itself escape. Its appearance shows that it also is subject to the general wearing

down and smoothing process, the rocks as they roll along ever grinding it deeper and deeper.

26. **Formation of River Valleys and Cañons.**—Thus the general tendency of rivers is to gradually deepen their beds or channels. As the material is cut out it is carried off by the running water. The banks of the river become undermined, and, falling into the water, are swept away. Rain, frost, &c., continue to act steadily on the rocks forming the hillsides, and each streamlet, as we have seen, after heavy falls of rain, bears down its load of rock material to the river As the result of all these processes river valleys are formed (fig. 7), the river ever cutting deeper and deeper, and the sides of the valley being opened out wider and wider. Hence wherever a river is seen with hills on each side, though at a considerable distance from its banks, we may be pretty sure that the land was once continuous and that the space between the hills has been cut out by the action of water aided by the other agencies.

Sometimes the valleys are deep and narrow, and are then called *passes*, *gorges*, or *ravines*. Such valleys occur where the rocks are hard and the river course steep. In regions where there is practically no rain there are no streams to wash away the sides of the gorges, and deep chasms called "cañons" are formed (fig. 4).

Some old valleys, we must note, are the result of glacier action, not of rivers of water. This will be understood from the next few paragraphs.

27. **Action of Glaciers.**—Glaciers are rivers of ice. They occur in regions of perpetual snow. The weight of the snow accumulating on the mountain sides causes the mass to move down the valleys in long tongues or sheets, and to these the name "glaciers" is given (fig. 15). On reaching a lower level the ice melts and forms a river.

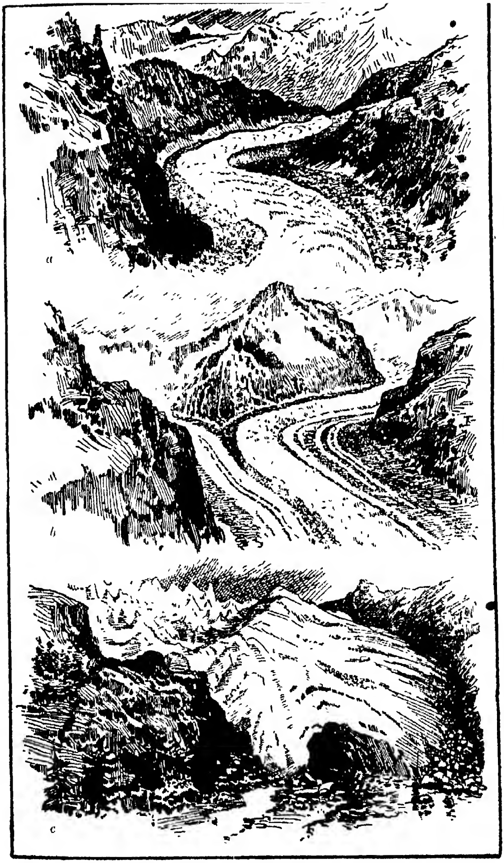

Fig. 15.—Glaciers and Moraines. *a* Lateral moraines; *b*, glaciers meeting and forming medial moraine; *c*, terminal moraine and ice cavern.

On each side of a glacier there is a continuous line of rock material, consisting of stones and rubbish, which has either fallen or been torn from the sides of the valley (fig. 15 *a*). These are termed *lateral moraines*, the word lateral (meaning "side") being used because the rubbish is spread along the margins of the ice-sheets, next the sides of the valleys.

Fig. 16.—Mass of Granite (perched block) resting on a Glaciated Surface of Rock

When two glaciers meet they move on side by side, the two adjacent, or inside, lateral moraines uniting and forming a *medial moraine* (fig. 15 *b*).

As the ice river moves slowly forward, great openings are continually occurring in it. Through these, stones

a *b* *c*

Fig. 17.—*a*, River-worn stone; *b*, wave-worn stone; *c*, stone worn by glacier

drop to the bottom, and, becoming frozen in the ice, are dragged along the surface of the valley. In this way, and also by the ice itself, the rock beneath the glacier

is polished, scratched, and worn away (figs. 16–8). The material produced by this grinding and scratching is carried forward by the glacier, and is known as the *ground moraine*. The sides of the valleys are also grooved and polished by the moving ice.

At the end of the glacier where it melts there is often an ice cavern. The stones and rubbish carried by the glacier are here thrown down into a great heap, called the *terminal moraine* (fig. 15 *c*). The water runs off through this material, and is consequently very muddy.

Fig. 18.—Stony Boulder Clay overlying Scratched or Striated Rock

28. **Boulder Clay.**—The amount of rock material carried away by glaciers is very great, and we must therefore regard them as powerful factors in the wasting of the land. At one time the climate of Britain was much colder than it is at present, and the valleys were filled with glaciers. Moraine matter, consisting of a stony clay called *boulder clay* (fig. 18), is accordingly found in many different parts of the country. Boulder clay is sometimes hundreds of feet in thickness.

29. **Boulders or "Erratics".**—Huge blocks of stone called *boulders* or *erratics* (or *wanderers*) have been deposited by glaciers in many different places. In

reference to the fact that these boulders are in many cases far removed from their native beds, the term "strangers" is sometimes given to them. Where boulder clay has been washed away, many boulders are to be

Fig. 19.—Boulder from the Arenig Hills of North Wales, found in Cannon Hill Park, Birmingham

found which are evidently "strangers" to the locality where they occur, no bed or mass of similar rock existing in the neighbourhood. In many instances boulders or wanderers have been left perched on other rocks, or in such places as the sides of valleys or tops of hills, and are then termed *perched blocks* (fig. 16).

CHAPTER VII

THE WASTING OF THE LAND—(*Continued*)

Action of the Sea—Enumeration of Denuding Agents—Formation of Soil and Subsoil—Rate of Denudation—General Results of Denudation.

30. **Action of the Sea.**—The destructive effect of the sea on rocks can be well understood by observing the fury with which waves break on the seashore during a storm. Fig. 20 gives a good idea of the power of

Fig. 20 —Rocks on Coast being worn away by the Sea

e sea at such times. Stones are caught up by the ıves and hurled against the cliffs with tremendous rce. The lower parts of the cliff are cut away, and e upper parts, thus undermined, fall ultimately into e water. Once there they become in their turn

4

battering rams, with which to break down additional masses of rock. In this way the face of the cliff is gradually worn back. The stones thrown against it are themselves broken by the impact, and by degrees reduced to sand as they are carried backward and forward by the waves.

31. **Enumeration of Denuding Agents.**—Something is now known of the main processes at work in wearing down the land. It has been seen that heat and cold, rain and frost, running water (whether in the form of tiny streams or great rivers, and whether above or below ground), ice, the sea, all play a part in the work of destruction. Wind, too, has its effect in carrying small fragments of rock material from a higher to a lower level, and in cutting away rocks by blowing sharp particles of sand against them, while the breaking up of the ground by the roots of plants and burrowings of certain animals assists greatly the actions of rain and frost.

Now the name given by geologists to this wasting away of the land is *denudation*. "To denude" means "to lay bare", hence "denudation" denotes "the act of laying bare". Applied to geology it means the laying bare of the underlying rocks, by the water and the other agencies wearing away the upper or exposed surfaces. "Denudation of the land", then, is a short way of referring to the process by which the land is broken up and removed, and its surface level gradually brought down to that of the sea.

The different means by which the denudation of the land is effected are called *denuding agents*. Heat, cold, frost, rain, running water, wind, and ice are termed *atmospheric denuding agents*, while the action of the sea on the land is known as *marine denudation*. Often wind, heat, cold, rain, and frost are called *weather*

agencies, their combined effect being spoken of as "weathering".

32. **Formation of Soil and Subsoil.**—It must not be thought that the work of the atmospheric denuding agents is confined to the more elevated parts of a country and to the exposed surfaces of rocks, for it goes on at all places—in low-lying districts as well as high, and even under the surface of the ground. By the action

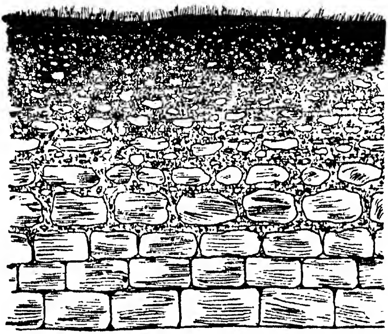

Fig. 21.—Formation of Subsoil and Soil from the Solid Rock

of the weather agencies on the rock underneath the surface of the earth we get *soil* and *subsoil*. A glance at the face of a quarry gives us an idea of the nature of the ground for some distance below the surface. On the top (fig. 21) there is a layer of soil or mould in which the grass and other forms of vegetation grow. Below the soil there is the subsoil, consisting of a layer of broken rock, while underneath the subsoil is the solid rock. The soil may be only an inch or two in thickness, or it may extend to a depth of several feet. The sub-

soil will probably be several feet in thickness. Now the subsoil is formed from the solid rock by the rain and other weather agencies acting on it and breaking it up into fragments. The fragments (or subsoil) thus produced continue to be acted upon, and therefore diminish in size with their distance from the solid rock. Near the surface the particles are very fine; and, becoming mixed with animal and vegetable matter, form soil.

The soil is, of course, thickest in flat-lying districts, because it is washed down from the sides of the valleys and hills as we have seen. But as no land surface is ever quite flat, the ground is gradually removed from the low-lying places also. Thus all rock material, whether coarse or fine (except what falls direct into the sea), tends to find its way into a river. But reaching the river is only a stage in its journey. As has been shown, it is moved forward by the water; and as all rivers flow either into a lake or the sea, the final resting place for the mud, sand, and gravel carried down must be the bottom of a lake or of the sea.

33. **Rate of Denudation.**—It will be interesting now to consider the *rate of denudation*, that is, the rate at which the surface of the land is being worn away owing to the action of the denuding agents. It is very evident that the amount of material carried off from the land in the course of only a single year must be very great. The denuding agents work slowly but they work unceasingly. Then, when we come to think of it, what an immense number of rivers there must be all over the land, each carrying its load of rock material to the ocean. Geologists are able to estimate the amount of material carried by any single river, and it is found that the great Mississippi alone conveys in one year into the Gulf of Mexico many million tons of

sand and mud. Added to this there is the invisible rock material dissolved in the water. The result is that the basin of this river is being lowered at the rate of 1 ft. in 6000 years. And some rivers perform the work of denudation at even more rapid rates than the Mississippi.

It is plain, then, that if there were no force or agency acting in opposition to denudation the whole land surface of the globe would ultimately be worn away and disappear under the waters of the ocean. But fortunately there is such agency, as we shall find in the next chapter.

34. **Denudation.**—As the conclusion to the present chapter it will be well to notice briefly some of the *general results of denudation*. As pointed out in § 32, the rock material borne by rivers is deposited in lakes or the sea. The lakes in consequence become filled up and converted into plains, while from the sand and mud laid down on the sea floor deltas are formed and new rocks built up (chap. ix). Then, though the denuding agents work continuously, they cannot remove the harder parts of the ground so quickly as the softer parts, and inequalities, or "ups and downs", in the land surfaces consequently result. Valleys, too, as has been shown (§ 26), are ever being widened, and the channels of streams and rivers deepened and enlarged. New valleys and hills are formed from tablelands, and mountains are made more rugged and steep. Thus through the action of denudation the face of the land is constantly undergoing change, and we get what is known as "scenery". To denudation, for example, the picturesqueness of many parts of Scotland is due.

We should ever have our eyes open to the natural features of the part of the country in which we happen to be, and it certainly does not detract from the pleasure of observing these to be able to trace each particular form to its causes.

CHAPTER VIII

MOVEMENTS OF THE EARTH'S CRUST

Elevation and Subsidence of Earth's Crust—Evidence of Elevation and Subsidence—Bending, Folding, &c., of Rocks.

35. **Slow Upward and Downward Movements (Elevation and Subsidence) of Parts of the Earth's Crust.**—In the preceding chapter we saw that if there were no force or agency acting in opposition to denudation the whole of the dry land would ultimately be submerged in the sea. Now denudation cannot be stopped. It must go on so long as there are denuding agents and land to denude. To counteract the effects of denudation, then, the land must either be lifted up or new land formed by the pushing up of the sea bottom. At the present time not only are certain parts of the land being slowly upheaved, but parts are gradually being sunk down or depressed, while in past ages there can be no doubt that such up-and-down movements must have repeatedly taken place. The result is that what was once the bottom of the sea is now dry land, and what was formerly dry land is now sea bottom. Tennyson knew this; hence he says:

"There rolls the deep where grew the tree,
O earth, what changes hast thou seen!
There where the long street roars, hath been
The stillness of the central sea".

These movements in the earth's crust have already been touched on. In chap. ii we saw that geologists are enabled to become acquainted with the rocks forming the crust only because the beds have been upheaved. Then the presence in the dry land of beds of shale

iv) indicates elevation of the sea bottom, but this is not surprising, because, as will be seen farther on, there is ample evidence that most of the area now occupied by the British Isles was at least once below sea level.

It is plain, then, that though denudation and subsidence tend to make the whole land disappear, yet elevation acts in opposition to these, and that while some parts are lost by one or other of these causes, yet other parts appear in their stead.

Then it must not be forgotten that by means of volcanoes (§ 13) fresh materials are brought up from the interior of the earth and added to the rock masses on the surface.

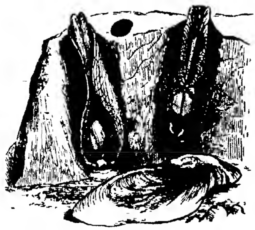

Fig 22.—Piddocks, or Rock-borers

36. Proofs of the Elevation and Subsidence of Parts of the Earth's Crust.—There are many proofs of the elevation of parts and subsidence of other parts of the earth's crust.

Elevation.—1. Raised beaches are to be found at certain places on our coasts, and also on those of other countries. These are beaches similar to the ones now found at sea level but occurring high above the water. They were formed by the action of the waves, then raised up by the elevation of the land.

2. Caves cut out by the action of the waves are now found far above sea level.

3. Marine shells are also found high above sea level.

4. Holes made by rock-boring shells (fig. 22) are now found above sea level.

Subsidence.—It is more difficult to find evidence of

subsidence, as when the land sinks down it is covered over by water and lost to sight.

1. At different places round our coasts submerged forests are to be seen at low tides. This shows that the land on which the forests grew sank down and was then covered over by water. Now only the stumps of the trees remain.

2. Other parts of the world are known to be slowly sinking.

37. **Rapid and Violent Elevation and Depression.**—The foregoing affords evidence of *slow and gentle* upward

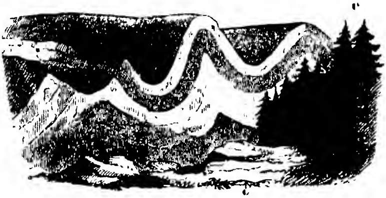

Fig. 23.—Section across the Jura Mountains, showing three anticlines and two synclines The crest of one anticline has suffered denudation

and downward movements of the earth's crust. *Earthquakes* are examples of *rapid and violent* elevation and depression.

38. **Cause of the Movements in the Earth's Crust.**—We come now to the cause of the movements in the earth's crust. It is very interesting to observe that these are believed to be due to the internal heat of the earth. Geologists think that there are several ways in which the upheavals and subsidences may have been brought about through the agency of the internal heat of the earth; the *cooling* of the interior is, however, believed to be the main cause. As the hot interior cools it contracts. The weight of the colder crust causes it to

sink down on the contracting interior. As the crust settles down the rocks forming it have less room. They are therefore squeezed violently together, and forced into a series of wrinkles or folds. Parts, therefore, are upheaved and parts depressed, the beds being bent, contorted, and broken (figs. 23–6).

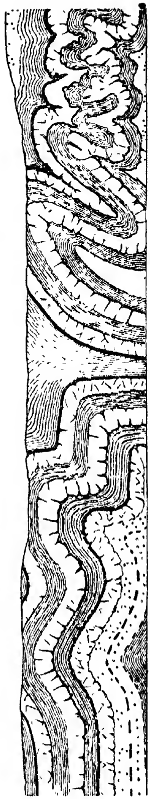
Fig. 24.—Contorted Strata

That the movements of the earth's crust are due to the cooling of the earth's interior is what is generally believed, some geologists ascribe the movements to an entirely different cause.

39. **Curved Strata.**—As will be seen farther on, *strata* simply means "beds of rock". Fig. 23 shows *anticlines* and *synclines*. The beds of rock have been bent or curved into the forms of arches (anticlines) and troughs (synclines). A book half-open, placed so that the back of the cover is uppermost, is in the form of an arch and represents an anticline. When placed so that it is resting on the back of the cover the half-open book is in the form of a trough and represents a syncline.

40. **Contorted Strata.**—When the beds of rock have been bent into violent curves or folds they are said to be contorted (fig. 24).

41. **Inverted Strata.**—Sometimes the beds of rocks are bent back over each other. They are then said to be inverted, that is, turned upside down

(fig. 25). The folding back of blankets on a bed will illustrate inverted strata. It will be seen that the top blanket becomes the bottom one of the fold.

42. **Faults or Dislocations of Rocks.**—Sometimes instead of bending into curves or folds the rocks break, and we then get what is known as a *fault* (fig 26, also figs. 51-4). When the rocks break, the beds are moved along the cut or fissure, hence we find parts of the same bed at different levels and a bed of one kind of material standing opposite a bed of another kind of material. The subject of faults will be resumed in chap. xii.

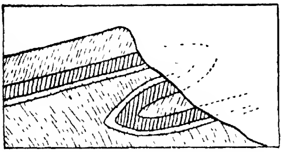

Fig 25 - Inverted Strata. The dotted lines indicate how the folding and inversion have taken place

An interesting experiment to illustrate folding of rocks may be performed by anyone as follows. Take a number of folded cloths of different colours, and arrange

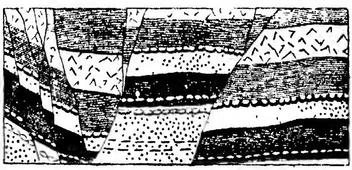

Fig. 26 —Section of Rocks traversed by numerous Faults

them in a pile by placing the bottom cloth horizontally on a table and the others above it—one on top of another. Put a book flatways on top of pile (to press it down) and also a book at each end so that a side of each of the latter is against an end of the pile. Now press the books at the ends of the pile towards each

other. It will be found that the cloths are thrown into "anticlines" and "synclines", and that the book on the top of the pile, now resting on the ridges of the anticlines, is higher than at the beginning of the experiment. The thickness of the cloths at the beginning should be such that the book on the top will just touch the ones at the ends. It is then clearly seen that the former has been moved upwards. Instead of books, pieces of board may be used. A heavy weight should be placed on the board or book on the top of the pile.

CHAPTER IX

FORMATION OF ROCKS

Deposition of River-borne Material—Deltas—Stratification—Sediment and Sedimentary Rocks—Fossils.

43 **Deposition of River-borne Material in Sea or Lakes.**—In this lesson we begin our study of the formation or making of rocks. The first to be dealt with are shale and sandstone. These rocks, we were told in chap. iv, are formed at the bottom of the sea or of a lake—shale from mud and sandstone from sand. We have seen how the mud and the sand are produced from the solid land, and have taken note of the vast quantities of these substances deposited by rivers in the sea and lakes. We must now enquire how the mud and sand are laid down in the bottom of the sea or lake, and how it is possible for such soft, loose materials to be changed into hard solid rocks.

EXPERIMENT.—Fill, to about an inch from their mouths, three tumblers with water; and into one put, say, a teaspoonful of very fine gravel which has been

well washed (or a teaspoonful of coarse sand free from fine particles), into another a teaspoonful of clean fine sand, and into the third a teaspoonful of mud or fine clay—made by drying the clay, then crumbling it into fine powder. Stir the contents of each tumbler, so as to mix thoroughly the water and the solid substance contained in it (it may be necessary to close the mouth of the tumbler containing the gravel and shake it up and down), and then observe the time that elapses before the water becomes clear. It will be found that the gravel drops to the bottom of the tumbler as soon as we stop stirring, leaving the water quite transparent. The fine sand does not fall to the bottom so quickly, yet does so in a very short time The clay may take many hours to settle, and even then the slightest movement to the tumbler will cause the water to become muddy.

Now let us compare the result of our experiment with what takes place when a river reaches the sea or a lake. In times of heavy rainfalls the river arrives at the sea or lake loaded with gravel, sand, and mud. As it enters the sea or lake its velocity is checked and immediately the gravel and coarse sand sink to the bottom, just as did the gravel or coarse sand in the tumbler the moment we stopped stirring. The gravel and coarse sand, then, carried down by the river, will be deposited near its mouth. The fine sand, we know, takes longer to settle, hence will be carried farther out, while the clayey matter, mingling with the sea water or lake water, will not fall to the bottom until a considerable distance from the shore. This, then, is exactly what was to be expected from our experiment with the substances in the tumblers.

44. **Deltas.**—Now, as the gravel, sand, &c., continue to be deposited, the sea will get shallower and shallower

near the shore (if the rock material is deposited in a lake the lake will be slowly filled up—§ 34). At last the mouth of the river will be quite blocked up and the water have to force its way through the deposited material. Sometimes in doing this it breaks up into two or more streams, the river thus having two or more mouths. These in time become blocked up also, and

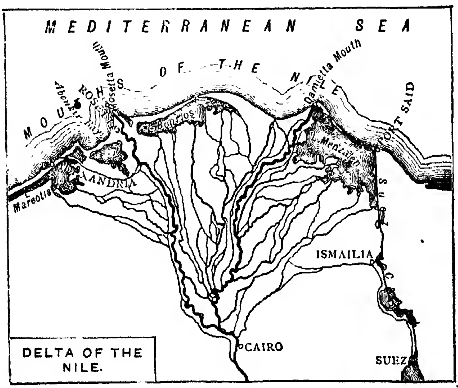

Fig. 27 Delta of the River Nile

other channels are formed. In this way both the shore line and the mouth of the river advance seaward, the sea next the shore always being filled up by, and new land formed of, the deposited material. This new land is called a *delta*, because similar in shape to the Greek letter of that name, Δ. It is therefore like a triangle. The broad part faces the sea (fig. 27), and each year becomes wider and higher. The point or apex is towards the course of the river, and is called the "head of the delta".

Extent of Deltas.—Many of these deltas are very extensive. Thus the whole of Lower Egypt (fig. 27), having an area of 12,000 sq. miles, has been formed out of the sand and mud brought down in past ages by the River Nile. It is called the "Delta of the Nile". The head of the Nile delta is at Cairo. The site of this town, then, must at one time have been on the shore of the Mediterranean Sea, though it is now 85 miles from it. This gives us an idea of how the shore line and the river mouth gradually advance seaward. It also compels us to think of the vast amount of rock material that must be discharged by some rivers over an extended period of time.

Absence of Deltas.—We must note, however, that deltas are not formed at the mouths of all rivers, the sand and mud being swept away by currents in the sea and deposited in other places in the form of *shoals* and *sandbanks*.

45. **Stratification.**—In the formation of a delta the mouth of the river, it has been seen, gradually advances seaward. Now the rock material will continue to be deposited in the order described in § 43, namely, coarse sand and gravel nearest the seashore, fine sand farther out, and clay farther out still. We can see, then, that as the mouth of the river advances we get fine sand deposited on clay and then gravel laid down on the fine sand. Thus we have three regular beds or layers of rock material, namely, clay at the bottom, fine sand above the clay, and gravel and coarse sand on the top of the fine sand. This is called *stratification*, from the Latin word *stratum*, meaning "strown out".

We can see, too, that if the floor of the sea near the shore were sinking continually, and therefore the shore line and mouth of the river retiring instead of advancing, we should still have the same regular arrangement of

the rock material, but this time fine sand would be deposited on the top of the gravel and clay or mud on the top of the fine sand.

If we take small quantities of gravel, sand, and clay and lay them down exactly as described in § 43, on a surface to represent the sea bottom, the order in which these substances are deposited becomes quite clear to us. The beds of clay and sand will get thicker farther out to sea (therefore "thin out" as we approach the shore line), and sometimes there are variations in the arrangement of the deposited material owing to changes in the velocity of the river and other causes. Also, as limestone is formed in the sea (chap. x), the mud, &c., may be deposited over beds of this substance or the former may be laid down, then limestone on the top, owing to the sea floor sinking, then again mud, &c. In this way we get beds of shale, limestone, sandstone, &c., occurring one on the top of the other in the earth's crust (fig. 28, also figs. 37, 38). Then sometimes in the earth's crust we find a bed of conglomerate passing into a bed of sandstone and a bed of sandstone or limestone passing into a bed of shale. This, it is evident, is accounted for by the arrangement of the gravel, sand, &c., on the sea floor. Fig. 28 helps to explain this also.

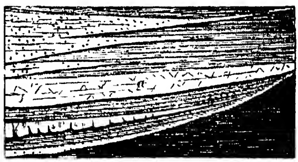

Fig 28 Strata thinning out and overlapping each other as they approach a shore line

46. **Sediment and Sedimentary Rocks.**—Now let us return to our experiment with the substances in the tumblers. If a substance is mixed with a liquid (*suspended in the liquid* we sometimes say) and then falls to the bottom, we call the substance a *sediment*. So

at the bottom of the gravel tumbler we have a *sediment of gravel*, at the bottom of the sand tumbler a *sediment of sand*, and at the bottom of the clay tumbler a *sediment of clay* or *mud*. Now suppose we had a great quantity of each of these sediments, and that the particles forming each were firmly cemented together, making hard, solid masses, then we should have three different kinds of rock, namely, a rock formed of gravel, or *conglomerate* (fig. 29), a rock formed of sand, or *sandstone* (fig. 30), and a rock formed of mud or clay, as *shale*. These three rocks would be called *sedimentary rocks*, because, as we have seen, they would have been formed from sediment.

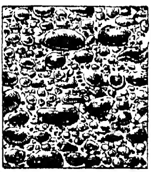

Fig 29.—Conglomerate, or Pudding-stone

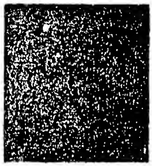

Fig. 30.—Fine-grained Sandstone of even texture

Conversion of Sediment into Solid Rocks.—Now what has been stated in the preceding paragraph indicates what goes on at the bottom of the sea. The great weight of the accumulated sediment, due to its thickness, causes a heavy pressure to be exerted on the bottom layers. The water is squeezed out, and the particles forced closer together. This in some cases is sufficient to convert the sediment into a hard rock, but in addition to the pressure there is generally some natural cementing agent which binds the particles firmly together, just as the stones in the sides of a house are held fast by the mortar. These natural cementing substances are contained in the water, and are deposited all round the particles of sediment. *The different colours of rocks are due to them.*

In this way, then, we get shale, sandstone, and conglomerate—shale being formed from mud or clay by pressure alone, sandstone from sand by means of pressure and some natural cementing substance, and conglomerate from gravel, also by pressure, and a natural cementing agent. And these rocks are called "sedimentary rocks" because they have been formed from sediment It is worth noting that they are also sometimes called *aqueous rocks*, because they have been formed under water (L *aqua*, water). The term *stratified rocks* is also used owing to their occurring in more or less parallel beds or layers, that being the way, as we have seen, the sand, &c, is deposited in the sea. This subject will be resumed in the next chapter.

Fig. 31 Slab of Shale with Impression of a Fossil Fern

47. **Fossils.**—Something must now be said regarding *fossils* (L. *fossus*, dug up). These (figs. 12 and 32) are the remains, or traces of the remains, of plants and animals found embedded in certain rocks of the earth's crust.

The plants and animals may have lived on the land and been swept down to the sea or into a lake by rivers in times of flood, just as branches of trees and the bodies of animals are at the present day. But most fossils are the remains of animals which once lived in the sea or in a lake or a river. When such animals died, their bodies became buried in the sand, mud, &c., at the bottom of the sea or lake. The soft parts decayed, but the hard parts, like the bones and teeth, were preserved, locked up, as it were, in the rock when

the sediment was converted into stone. These hard parts, then, are the fossils. They are the actual preserved remains of the animal, and are found when we penetrate into the rocks.

But the name "fossil" is not confined to the actual remains of plants or animals. As seen from the definition at the beginning of the preceding paragraph, it is applied also to "traces of the remains". Thus, for example, instead

Fig. 32 - Footprints and Tooth of Large Amphibian found in Sandstone

of the actual parts of plants or animals, we may find mineral or stony substances which have their exact shape. Such mineral or stony substances are also called fossils. It is interesting to note how they are produced. It is owing to the action of water, which, as it percolates through the rocks, dissolves away the remains of the plant or animal and deposits stony matter in their place. Then again we may find only a cavity or hollow, but which yet has the exact shape of the part of the plant or animal, and this, too, is called a fossil. Such cavities, or hollows, are also due to the action of water, the actual fossil remains of the plant or animal having been dissolved away, but no mineral or stony matter left in their stead. Lastly, ripple marks, rain pittings, and footprints (fig. 32) can sometimes be seen in rocks, and to these also the name fossil is applied.

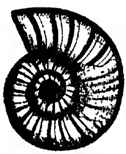

Fig. 33 —Ammonite

In early times fossils were believed to be the remains of animals which were drowned in the Flood, hence were sometimes termed "Antediluvian animals". Fossil shells

called *Ammonites* (fig. 33) from their shape were thought to be petrified snakes. Sir Walter Scott alludes to this in *Marmion* (ii. 13):

> "And how, of thousand snakes, each one
> Was changed into a coil of stone".

CHAPTER X

FORMATION OF ROCKS—(*Continued*)

Organically-formed Rocks—Limestone—Coal. How Found—Stratified Rocks—Section of Strata—Dip—Strike—Outcrop.

48. The rocks now to be considered are *limestone* and *coal*. These are called *organically-formed rocks* (that is, rocks formed from the *organs* or parts of once living plants and animals), limestone having been derived mainly from the bodies of animals, and coal from those of plants.

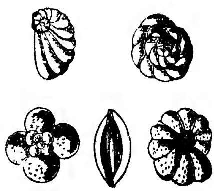

Fig. 34.—Shells from the Chalk (highly magnified)

49. **Limestone.**—Every person is familiar with the appearance of *chalk*. Now chalk is merely soft, whitish limestone, and if a little of it is prepared and examined under a microscope traces of the dead animals of which it is composed can be seen. It is found to consist for the most part of tiny shells and fragments of shells. Some of the shells are shown in fig. 34. It will be seen that they are of different shapes. Now these shells were formed in the sea by little animals that lived there. These little animals, about the size of a pin head, had bodies soft like jelly. They formed their shells from

a substance (called "carbonate of lime") dissolved in the sea water, and lived inside them. When they died their soft bodies soon perished, but their hard shells or skeletons accumulated on the sea bottom and were gradually compressed into rock.

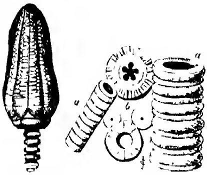

Fig 35.—Encrinites or Sea-lilies

a a, Portions of jointed stems, *b*, separate joints The cup and head, with tentacles closed in, is seen on the left

Such, then, is how chalk has been formed, and most other limestones have been produced in a similar way. The little animals must have lived in countless millions, for limestone is a very common rock, and a vast number of shells would be necessary to make only a very small piece.

Mountain Limestone—A well-known variety of limestone is that known as the *mountain limestone*. It is composed of the joints of marine animals termed *encrinites* or sea-lilies (figs. 35, 36), corals, and shells, including the shells of the little animals already described.

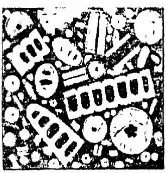

Fig 36 Section of Mountain Limestone Rock full of Fragments of Encrinites

This limestone receives its name from the fact that it often forms hills It is well seen in Derbyshire and other parts, and gives us an instance of a rock formed at the bottom of the sea now occupying an elevated position. It shows that the parts of England where it is now found must long have formed the bottom of a sea (§ 85).

50. **Coal: How Found.**—Coal, we saw in the introductory chapter, occurs abundantly in Britain, and in large or small amount in most countries. As mentioned

in chap. iv, it is found in beds or sheets called "seams". Some of the seams are of very large area, others of comparatively small extent. The thickness also varies greatly, running from a fraction of an inch to many feet. The thickest coal seam in Britain is the "Dudley

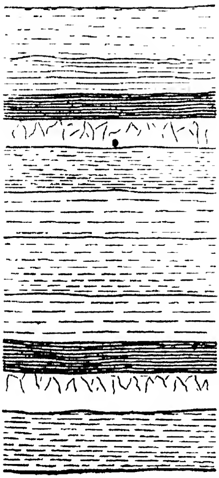

Fig. 37.—Strata showing Seams of Coal, between which come Beds of Sandstone, Shale, and Clay

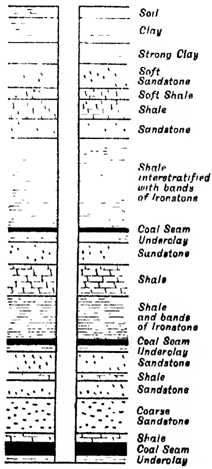

Fig. 38.—Section of Coal Shaft

Thick", or "Ten-yard Coal", in South Staffordshire, which ranges from 25 to 35 ft., but much thicker seams are found abroad. When a seam is very thin it is, as a rule, unprofitable to work, and when very thick much coal is usually lost in the extraction of it.

Some seams of coal occur at the surface (figs. 39, 40);

others lie hundreds of yards down. Usually there are several seams at different depths and more or less parallel (see figs. 37, 38). In many such cases two or three of the seams are worked at the same time, the coal being brought to the surface by means of the same shaft or opening (fig. 38). Generally the seams nearest the surface are worked first, but as time goes on these become exhausted and the deeper seams have then to be opened up. Men, therefore, have to descend farther into the bowels of the earth to work the coal than they formerly did; and in the future they will have to go down to even greater depths.

51. **Stratified Rocks**—In fig. 37, it will be noticed, a regular recurrence of beds of rock is shown—first (beginning at the bottom) sandstone, then underclay, then coal, then shale, then again sandstone, &c. The reason for this arrangement of beds will appear in the next chapter, but we must here note that such an arrangement gives us another instance of "stratification". As we saw in § 46, when rocks occur in more or less parallel layers, such as is shown in fig 37, and as perhaps may be seen in a quarry, railway cutting, or sea cliff, they are said to be "stratified". Coal, like sandstone and shale, is therefore a "stratified rock", as also is limestone (see again fig. 28) It should be noted that *one* of such beds is called a *stratum*, while *two or more* adjacent beds are referred to as *strata*, this word being the plural of stratum. Thus in fig. 37, the strata shown consist of eleven beds or layers any one of which is a stratum. Then we must not forget, as indicated in the preceding chapter, that when rocks are stratified it shows that the material composing them was laid down in regular beds or layers—one on top of another, the bottom layer having been deposited first.

52. **Section of Strata (or Geological Section).—Fig. 37**

serves also to illustrate what is known as a *section strata* (or *geological section*). If we cut any obj through so as to show its interior, we obtain a "s tion" of the object, and, similarly, we get "sections strata" when we cut down, more or less perpendi larly, into the rocks. We can see sections of strata quarries, railway cuttings, and sea cliffs. Holes bor deep into the ground and shafts sunk down to c seams (fig. 38) give sections which show the thickn and nature of the beds to considerable depths.

Sections of strata, it should be understood, are eitl *vertical* or *horizontal*. Those which show the ord thickness, &c., of the beds at any place, as in the ca of shafts or boreholes, are termed *vertical sections*, wh those which show the general arrangement of the stra along any given direction, as, say, in the case of a ra way cutting or canal, are called *horizontal sections*.

It is plain, then, what a section of strata is; and a such opening into the rocks, whether it is natural artificial, is of use in showing the form and positic of the beds; but geologists, we must note, are able draw on paper *ideal* or *imaginary* sections. Th have special maps, termed "geological maps", whi have been constructed to show the rocks appearing the surface in different localities, and from the infi mation contained in these maps a geologist can down in his room and make drawings or diagra showing the general arrangement of the rocks eitl vertically at any place or horizontally between a two places. Thus it is quite possible for a geolog to make a drawing (or "section on paper") showi the general arrangement of the rocks between, sa the east and west coasts of England, across Scotlar or between any two points represented on the geologi map, without having to cut into the ground. T

drawings or diagrams are also termed "sections", and therefore we have to be careful to distinguish between *a section as shown on paper and a real section. Fig. 60 shows a section constructed from a geological map. It will be better understood after chap. xvi has been read.* Geological maps will also be referred to in chap. xvi.

53. **Horizontal and Inclined Seams, Dip of Strata.**—Now let us return to our consideration of the mode of occurrence of coal seams. Some seams are found lying quite flat, but most are more or less inclined (figs. 39, 40), and may even be vertical.

Fig 39 Coal Measures occurring nearly horizontal

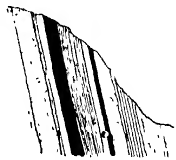

Fig 40 Coal Measures occurring nearly vertical

Now, the inclination of a seam of coal, or of any bed, is called its *dip*, and is measured by the angle which

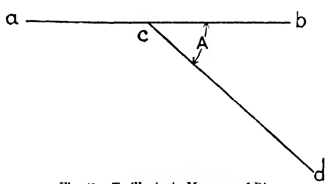

Fig. 41.—To illustrate Meaning of Dip

the bed makes with a horizontal plane. Thus, if we hold a slate in a perfectly horizontal position, *a b* (fig. 41), the under side of it will represent a horizontal plane. Another slate, held in the position *c d*, making an angle A with the first slate, will stand for the bed

or seam, while the angle A will be the dip of the seam, or the amount it inclines or slopes away from the horizontal position.

If the slate cd is held halfway between the horizontal and the vertical, then the angle A will be 45 degrees and the bed *cd* will have a dip of 45 degrees. If *cd* is vertical, then the angle A will be 90 degrees, and therefore the dip of the bed 90 degrees. We see, then, that if the dip is 0 degree, the bed is horizontal; if 90 degrees, that it is vertical; while a dip between 0 and 90 degrees indicates that the bed is occupying a position between the horizontal and the vertical. The amount of the dip of a bed is ascertained by means of an instrument called a *clinometer*, a simple form of which it is very easy to construct.

It is always well to note the *direction* of dip as well as its amount; that is, whether the bed dips in the direction of north, south, east, or west, &c. The slates on the roof of a house may be taken to represent two beds dipping in opposite directions, while an anticline or a syncline (fig. 23) shows the *same* beds dipping in opposite directions. Inverted strata dip in an opposite direction to what they did at first.

When speaking of inclined seams, miners use the term *rise* as well as dip. Thus, if the seam is being worked downhill, they say that it "dips", or is being "worked to the dip", but if uphill that it "rises", or is being "worked to the rise". Again, they often state the amount of dip in inches per yard instead of degrees. Thus a dip of 1 in. per yard would mean that the seam dipped 1 in. in each yard of distance; a dip of 2 in. per yard, that it would dip 2 in. in each yard of distance; and so on. If the seam were being worked uphill, the miners would speak of a *rise* of 1 in. per yard, 2 in. per yard, &c. Then the expression 1 in "so many", as, for

example, 1 in 4, 1 in 5, 1 in 6, &c., is often also used. Here a dip of 1 in 4 would mean that the seam dipped 1 in each 4 of distance, as 1 in. in 4 in. of distance, 1 yd. in each 4 yd. of distance, 1 mile in each 4 miles of distance, and so on. As before, if going uphill, the miner would speak of a rise of 1 in 4, 1 in 5, &c., as the case might be. Fig. 42 also illustrates dip.

54. **Strike.**—Fig. 42 illustrates another term used by geologists, and also by miners, namely, *strike*. The strike of a bed is the line or direction at right angles to the

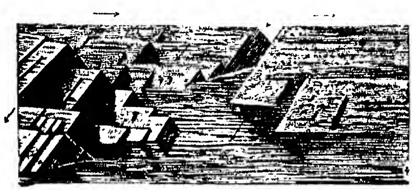

Fig. 42.—Dip and Strike. The horizontal arrows indicate the strike; those pointing towards the left-hand lower corner show the direction of the dip.

dip. Thus, if a slate is held or fixed in a sloping position and a drop of water placed on it, the water will run down the steepest part of the slate. The track of the water will represent the line of dip, while a line drawn at right angles to it will be the line or direction of the strike.

If the dip of a bed is due south, then the direction of the strike will be due east and west. Again, if the line of strike is east and west, then the bed must dip either to the north or to the south. This can be compared to the slates on the roof of a house, the ridge representing the line of strike.

The line of strike, being at right angles to the dip, is always a perfectly horizontal or level line. This may

be shown by walking full to the dip and then to the rise. If now we proceed at right angles to our former course we shall be going neither to the dip nor rise, but along the horizontal or level. Miners usually speak of the direction of no dip as *level-course*, and a road which is being driven at right angles to the full dip, or in the direction of no dip, is said to be "going level-course".

55. **Outcrop.**—An inclined seam of coal may appear at the surface, and is then said to *outcrop* (figs. 39, 40). This word is used both as a noun and a verb, the part of the seam seen at the surface being called "the outcrop". From fig. 39 we can see that it is possible for horizontal strata to outcrop if the beds terminate in the side of a valley or hill. In searching for coal in a new or unexplored district the discovery of an outcrop is of the greatest importance.

Another name sometimes used instead of outcrop is *basset*. It is the outcrops of strata that are represented on geological maps.

CHAPTER XI

FORMATION OF ROCKS—(*Continued*)

Coal: Formation, &c.—Peat—Lignite, &c.

56. **Proofs that Coal has been Formed from Vegetation.**—We saw in § 48 that coal is an "organically formed rock", having been derived from the remains of plants. We can prove this to be the case in several ways. If, for example, very thin slices of coal are examined under a microscope, the spore cases or seed vessels of plants can often be seen, also traces of bark, &c. Then, by treating coal in a certain way, called

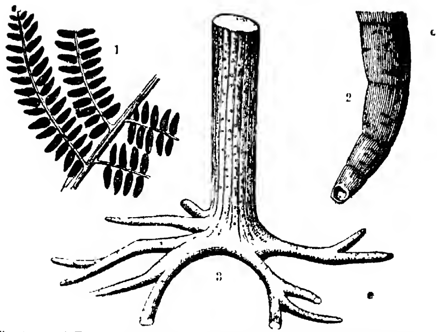

Fig 43.—1, A Fern, 2, Calamite, a "horse-tail"; 3, Sigillaria, with its roots (known as Stigmaria) attached

"analysing it", its composition is found to be such as if it had been formed from vegetation. Again, the bed of rock, called "underclay" (fig. 37), which is found under most coal seams is frequently penetrated by roots of plants, while the coal itself, or stratum of rock above it, may contain the fossil trees, or parts of their stems,

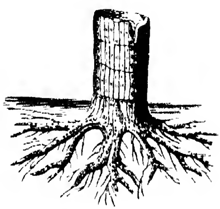

Fig. 44.—Sigillaria in a Coal Mine near Liverpool

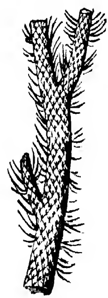

Fig. 45.—Lepidodendron or "Scale-tree", so named from the leaf-scars on stem

belonging to these roots (fig. 44), as well as impressions of ferns or other plants (fig. 31).

Figs. 43–5 show some of the plants from which coal has been formed.

57. **The Underclay an Old Soil.**—Now, seeing that coal has clearly been formed from vegetation, and that the underclay, or bed under the seam, sometimes contains roots, we must conclude that the underclay is the old soil on which the vegetation now changed into coal grew. Such is believed to be the case. Of course underclay does not now resemble soil. It is, in fact, a hard, greyish-coloured rock. But we must remember that it has been buried for ages in the ground, and that the pressure of the strata above it would harden it into solid rock. At the time the coal-forming plants were growing it would be at the surface, and would then be soil.

Absence of Underclay.—Where there is an underclay, then, the vegetable matter forming coal would grow on the area or spot now occupied by the coal. But this could not be the case where, as sometimes happens, there is no underclay under the seam and no trace of roots. In such circumstances it is believed that the coal-forming plants drifted from adjacent land and were deposited on the area on which the coal is found.

58. **Conversion of Vegetable Matter into Coal.**—The question of how the vegetable matter was changed into coal now arises. Well, we know that if vegetable substances, such as leaves, &c., are left lying on the ground, they decay and go to form part of the soil. That is because they are acted on by the air. But if the vegetable substances are protected from the air, as by being buried in the ground, and are subjected to the actions of pressure, heat, and moisture, it is found that they do not crumble into powder and disappear, as when exposed to the air, but are gradually changed into coal; or they

become, as we say, *mineralized*, that is, converted into a mineral or stony substance. Now, that is the way in which coal is believed to have been formed, hence we often speak of coal as "mineralized vegetable matter" or "mineralized vegetation", &c. The coal-forming vegetation, as we shall see towards the end of the present chapter, became buried in the ground under immense heaps of mud and sand, now found as shale and sandstone (figs. 37, 38) Thus the pressure upon it would be very great. The temperature would increase, as the buried mass was protected from the action of the air, and thus, under the combined effect of pressure, heat, and moisture, the vegetation would be converted into coal.

It is known that vegetable bodies are composed of the substances called "carbon", "hydrogen", "oxygen", and "nitrogen", in proportions which vary with the variety of plant. Carbon is a heavy, *solid substance* that can be seen and handled like a piece of wood or stone. Hydrogen, oxygen, and nitrogen are *gases* which we cannot see, just as we cannot see air, or coal gas when we light it at the jet. Now it is found that when vegetation changes into coal the proportion of carbon increases, while that of each of the other substances decreases. This is seen from the following table:—

Substance	Percentage of Carbon.	Percentage of Hydrogen.	Percentage of Oxygen and Nitrogen.	Weight of a C. Ft. in Lb
Wood . .	50	6	44	31
Peat	60	6	34	53
Lignite .	68	5	27	65
Common Coal .	86	5	9	81
Anthracite .. .	95	2·5	2·5	93

The wood represents the vegetation, and the table

shows the increase in the proportion of carbon and decrease in the other substances as we advance from wood to peat, from peat to lignite, lignite to common coal, and common coal to anthracite. The table also shows the approximate weight of a cubic foot of each substance, and we can see how this increases as the substance grows richer in carbon.

Peat.—Peat is found in bogs and marshes, and when dried is used as fuel. It is a vegetable substance, as can be seen by examining it, formed by the growth and decay of mosses and other marsh-loving plants. The mosses, &c., grow on the surface of the peat bed, and as one generation dies another springs up in its place, in this way adding to the thickness of the decaying mass. The vegetation at the surface is green, but a few inches down we find the dead leaves, roots, &c., compressed together and the colour brownish. Farther down still the mass is more compressed and the colour darker, the appearance being now more like that of coal. The vegetation has, in fact, become partially mineralized. It has lost some of its hydrogen, oxygen, and nitrogen, and gained in carbon (see table). Peat, then, may be regarded as showing the first stage in the conversion of vegetable matter into coal.

Lignite.—Lignite shows the next stage. As seen from the table, it has more carbon than peat, and less of the other substances. It is coal, but not true coal, and is often described as "vegetable matter incompletely mineralized". It is brown in colour.

Common Coal.—Common coal shows the third stage. It has much more carbon and much less of the other substances than lignite.

Lastly we come to *anthracite*. This also is coal, and, as we see from the table, has become so completely mineralized as to consist almost entirely of carbon.

59. **How the Coal comes to be Buried under Sandstone, Shale, &c.**—We must now see how the vegetation from which coal has resulted became buried under the masses of mud and sand found at the present time as shale and sandstone. It was due, in the first instance, to the sinking of the land. The coal-forming plants grew, it is believed, in swamps, or marshy areas, not much above sea level (fig 46). The climate was warm and moist. The vegetation sprang up quickly, then died, and accumulated on the land. The land sank slowly, as we learnt in chap. viii, and the vegetable mass disappeared under the surface of the sea. Mud and sand brought down by rivers were spread over it. In course of time the sea bottom became filled up, as we saw in the formation of deltas (§ 44), and a new land surface was formed. Vegetation again sprang up, died, and accumulated. Again the land sank slowly, and the second vegetable deposit became covered over with mud and sand. Once more a new land surface would be formed, and the operations of growth, accumulation, subsidence, and deposition of mud and sand repeated. As the subsidence continued, and the deposits of mud and sand grew thicker, the pressure on the buried vegetable mass would become greater and greater, and so it would be gradually changed into coal. The underclay would be hardened into rock, and the mud and sand converted into shales and sandstones — all in the manner we have already learnt.

In this way, then, the coal-forming vegetation is believed to have been buried, and in this way we can account for the beds of underclay, coal, shale, and sandstone occurring as shown in fig. 37. Each bed of underclay represents an old land surface, each seam of coal the vegetation that grew on that surface, and each bed of shale or sandstone the mud or sand brought down

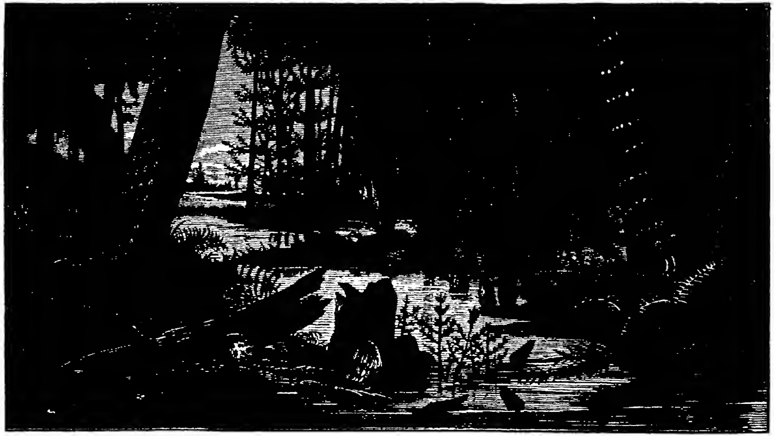

Fig. 46.—Restoration of a Coal-measure Forest, showing Sigillaria, Lepidodendron, Calamites, Ferns, &c
Fishes and amphibia swim in the waters of the old swamp

by rivers and deposited on the top of the submerged vegetation. When a coal seam is thick it means that the surface of the land remained undisturbed for a long enough period to enable large masses of vegetation to accumulate; when the seam is thin, that the land surface was stationary for a comparatively short interval. Again, great thicknesses of shale and sandstone between the coal seams indicate that the subsidence extended over a long period, while alternations of shale and sandstone, and changes in the same bed from shale to sandstone, or sandstone to shale (§ 45), show that at times the depth of the water varied, the mud being deposited in the deeper areas and the sand in the shallower, just as we saw was the case in chap. ix.

In the working of coal seams we meet with many irregularities which we are able to explain when we know how coal has been formed. These will form the subject of the next chapter.

CHAPTER XII

FORMATION OF ROCKS—(*Continued*)

Irregularities in Coal Seams—Rolls, Swellies, &c.—Variations in Quality, &c.—Faults.

60. **Irregularities in Coal Seams.**—It is very seldom that a seam of coal remains uniform in all respects throughout its entire extent.

Rolls.—Sometimes in working the seam we may find the thickness to decrease on account of a sudden rise in the floor without a corresponding elevation of the roof. Such an occurrence is known as a "roll" (fig. 47). Rolls are believed to be due to inequalities in the surface of

the ground on which the coal-forming vegetation was deposited. They are very frequent in mines.

Swellies.—A "swelly" (fig. 48) is a thickening of the coal caused by a depression in the floor. Swellies are also believed to be due to inequalities in the old land surface.

Nip-outs.—Sometimes the roof and floor of a seam are

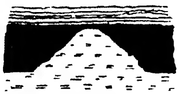

Fig. 47.—A "Roll"

Fig 48—A "Swelly"

found to approach each other, so that the coal diminishes in thickness, and may ultimately die out. This is sometimes termed a "nip-out".

Wash-outs.—"Wash-outs" (fig. 49) are thought to be the result of the action of rivers which first cut or "washed" away the coal or coal-forming vegetation, and then deposited sand, gravel, &c., in its stead. The

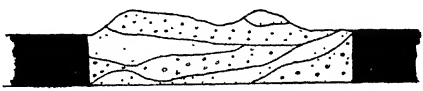

Fig. 49—A "Wash-out"

distance between the ends of the seam is sometimes considerable, as if a valley had been formed and then filled up. Miners usually speak of wash-outs by the name of "want", this term being used generally to indicate barren or "dead" ground.

61. **Splitting, &c., of Coal Seams.**—In the working of coal we sometimes meet with bands of stone which split up the seam into two or more layers. Such an occur-

the other case we must cut up or dig down, according to whichever part of the seam we happen to be in. Miners usually have names of their own for the different kinds of irregularities to be found in coal seams, and often the name for the same kind of occurrence is different in different localities. The term "trouble", for example, is a very common one, and is applied to all sorts of irregularities. Thus, if a seam has many dykes, intrusive sheets (chap. xiv), or faults, it is said to be "troubled". The word "step", too, is often used instead of "fault", while if the vertical movement of the beds is only a few feet the term "hitch", "heave", and "slip" are employed.

In fig. 51 *ff* indicates the *plane of the fault* (or "fault plane"), that is, the plane along which the beds have been moved. Or, if we prefer it, we can say that it represents the "break" or "fissure" in the rocks (or "line of dislocation" or "fault fissure"). But in any case we must note carefully as to the width of the fissure. From the line used in diagrams to represent it (*ff*, fig. 51, for example) we are apt to think that it can be nothing more than a crack. That is frequently the case, the rocks fitting so closely together as to render it impossible to insert anything thicker than a knife blade between them, but often the fissure is several feet in width and may be as much as several yards. Such fissures are usually filled up with solid rock matter, termed *fault rock* or *fault breccia*, consisting of rock fragments which were torn from the beds as they were forced past each other, and afterwards bound together into a solid mass. Sometimes they also contain mineral substances which have been deposited by water. Then sometimes the walls of the fracture are finely polished and grooved by the grinding of the rocks against each other. This is called ***slickensides***. The crack or fissure,

it will be observed, is more or less inclined; in some faults, however, it is vertical. Very often the crack or fissure is termed the fault, but we must notice that a mere crack or fissure does not constitute a fault. To have a fault as the geologist understands it there must be movement of the strata as well as a fracture.

64. **The throw of a fault** is the amount of *vertical* displacement of the beds, or the distance they have been moved *straight up or down.* To be able to tell, then, the throw of a fault in the case of any coal seam, we must know the perpendicular distance from the floor of part of seam on one side of fissure to floor of part of seam on the other side (AB, fig. 52.) (Or we may measure from roof to roof if we prefer.) We must be very careful not to confuse "throw" with AC, the distance the beds have "slipped" or been moved along the fissure. It is not of much importance, but it may be mentioned that this is called the *slip*, while BC, or the amount the beds have "shifted" or moved horizontally, is termed the *shift* of the fault The distance BC is also called the *width* of the fault. The width of the fault denotes the extent of the barren ground.

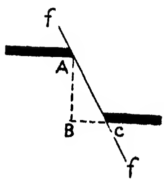

Fig 52. Ordinary or Normal Fault

AB = throw, angle BAC = hade.

The throw of faults varies from a fraction of an inch to thousands of feet. When it is not more than a foot or two, miners, we have seen (§ 63), term the dislocation a "hitch", "heave", or "slip". Other terms sometimes used to denote faults are "checks" and "slides".

Downthrow or Upthrow Fault.—A fault is called a *downthrow* or *upthrow* according to the part of the seam or bed in which we happen to be when approaching it. Thus, if we are in the upper part of seam (A, fig.

52), we say the fault is a "downthrow", while if we are in the lower part (C, fig. 52) we say the fault is an "upthrow". Thus the same fault is both a downthrow and an upthrow to a person approaching it from different directions. Other names for "downthrow" are *dipper* and *downcast*, and for "upthrow" *upcast* and *riser*.

Hade.—This is another term used in connection with faults. If we are working in a seam and strike a fault we must find out whether it is an upthrow or downthrow. Here a knowledge of the hade is of great value, but as the rule can be reduced to a simple practical form we need not trouble about hade further than to note what it is. The hade of a fault, then, is simply the inclination of the fault plane. In measuring it the amount the fissure inclines or slopes away from the *vertical* is taken (not from the horizontal as in the case of "dip of a bed"). Fig. 52 makes it quite clear.

CHAPTER XIII

FORMATION OF ROCKS—(*Continued*)

Faults (*Continued*)—Varieties of Faults—Finding the Continuation of a Seam Broken by a Fault.

65. **Varieties of Faults.**—Faults are of several kinds. Figs. 51, 52 show *ordinary* or *normal faults*. As implied by the name this variety of fault is very common. It occurs with more or less throw in most collieries.

Reversed or Overlap Faults (Fig. 53).—This kind of fault, as indicated by the first of the names used, is the reverse of the ordinary fault. Here the beds have been pushed over one another so that they *overlap*. Reversed faults are rare in coal mines.

Trough Faults.—These consist of two faults, the fis sures of which hade or slope to each other (see fig. 54) The beds thrown down are of the shape of a wedge It will be seen that a trough fault constitutes both a downthrow and an upthrow fault whether we are working the seam from the left to the right or right to left.

Step faults are a number of parallel faults occurring one after the other so that the strata appear as if let down in a series of steps (see left of fig. 26). The throw of any one of the faults may be very little, but the total amount very great.

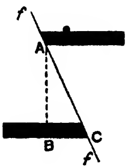

Fig 53.—Reversed Fault
AB = throw; angle BAC = hade.

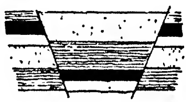

Fig. 54 —Trough Fault, in which the beds are thrown down 18 ft.

66. Finding the Continuation of a Seam Broken by a Fault.—When a seam of coal which is being worked is found to be cut off by a fault, steps must be taken to discover the lost portion of the bed. The question of whether the fault is an upthrow or downthrow first arises, and then must be ascertained the amount of the throw. In answering the question as to the direction of displacement, the hade, as has been mentioned, is of great service. The rule is that the fault hades or slopes to the downcast side (A to C in fig. 52), but taking the simplest possible way of this we say that if the fault plane leans to the observer at top and away from him at bottom it is a downthrow (A fig. 52), while if it leans to him at bottom and away

from him at the top it is an upthrow (C, fig. 52). This is quite clear if we imagine ourselves to be standing in the seam looking at the face of the fault rock, first at A and then at C.

But we must remember the above rule applies only to *ordinary* faults. Thus, if we look at fig. 53, which shows a reversed fault, we can see that the very opposite is the case, a crack or fault plane leaning to the observer at the top and away from him at the bottom, indicating an *upthrow*, and vice versa. This is because reversed faults are the opposite of ordinary faults, hading to upthrow side (A to C in fig. 53) instead of to downthrow side, as in the case of ordinary faults. But we need not trouble ourselves about the reason, or the fact that the rule does not apply to reversed faults, because this kind of fault is so rare in coal mines its existence is ignored and the dislocation assumed to be a normal one until the opposite is actually known to be the case. We therefore always follow the rule given in the preceding page, unless we have reason to believe that the fault is a reversed one.

Besides the guidance afforded by the hade, other indications are looked for as to the direction of displacement. Thus the seam may be found to rise a short distance away from a downthrow fault and to dip on approaching a rise fault, but this is not regarded as a good sign. A better one is the thinning or "tailing out" of the coal in the direction of the displaced bed. The tailing arises from the fact that the beds bend a little before breaking; the bent ends therefore thin out in the fissure and lie towards each other. This indication is of especial value when the fault fissure is nearly vertical.

Having made up our minds as to whether the fault is an upthrow or downthrow, we proceed to ascertain

the position of the displaced bed. It may be possible to find it by following the fault fissure, or "vees" as it is sometimes called. If that is not successful a drift may have to be driven through the fault rock, and the beds on the other side examined and compared with a section of the seam (§ 52). If this also is unsuccessful a borehole may have to be commenced near the face of the drift, being made in an upward or downward direction as the case may be (sometimes in both in cases of doubt). The section of the strata so obtained is compared with the shaft section, and this may lead to the location of the coal. Sometimes the borehole is continued right into the seam. The throw now being ascertained, the steps deemed necessary to win the faulted portion of the seam can be gone on with. Sometimes finding the position of the coal cut off by a fault is termed *proving the fault.*

67. **Effect on the Coal of Faults.**—It is interesting to note the effect of faults on the coal next the crack. Sometimes there is no change either in its quality or nature, but usually it is inferior, and either harder or softer. The thickness also generally varies, sometimes increasing, but more usually decreasing, next the fault. Often the ends of the beds are much broken, and the changes so great as to indicate the presence of the fault before the fracture is actually reached.

Occurrence of Faults.—In regard to this it may be said that often when one fault is met with others are found to occur parallel to it, that sometimes two sets of faults run at right angles to each other, and that frequently a large or main fault is found to split up into a number of minor or branch faults.

CHAPTER XIV

FORMATION OF ROCKS—(*Continued*)

Igneous Rocks—Fragmental and Crystalline Igneous Rocks—Dykes and Sills—Minerals.

68. **Formation of Igneous Rocks.**—We have now reached the hard rocks such as basalt and granite. These are called *igneous* (or "fire-formed") *rocks* (L. *ignis*, fire), because they have cooled down and solidified from a molten state. They are the result of volcanic action in former times. The lava, we have seen (§ 13), comes from the interior of the earth, where it is very hot. When it cools, igneous rocks are formed.

Such in brief is how igneous rocks originate, but it will be well to consider the matter a little more fully.

When a volcano (fig. 6) is in action large volumes of steam and gases are discharged into the air with great force. The steam and gases are pent up in the ground, and in finding their way out break off pieces of stone from the sides of the vent and crater. These are forced high up into the air, accompanied by clouds of ashes and dust.

The steam condenses into water and falls as rain. The stones and ashes drop all around the volcano, and may afterwards be cemented into rock by the mud formed from the dust and falling rain, or they may remain quite loose and incoherent.

Sometimes the dust and steam rise to heights of several miles, and the former, being caught by upper currents of air, may travel for long distances before settling down. It was in this way that Pompeii and other cities became overwhelmed by the dust of Vesuvius in 79 A.D. Mud streams may also be formed. The

town of Herculaneum was buried by such a stream in the same eruption as destroyed Pompeii.

Following the discharge of the steam, &c., the lava rises in the vent. This sometimes does not reach the surface. When it does, lava streams are formed, and these may extend for many miles. Whether the lava overflows at the surface or not, there will always be a large supply deep down in the ground, and when this cools rocks will be formed just as they are from the molten matter on the surface. But we note that the molten matter which rises to the surface, or comes near to it, will lose its heat much more rapidly than the material which remains at considerable depths.

69. **Fragmental and Crystalline Igneous Rocks.**—Now it is plain that there must be a great difference between the igneous rocks formed from the stones, &c., discharged from the volcano and those which result from the cooling down of the lava. The former are made up of fragments—pieces of lava solidified from a former eruption and plugging up the top of the vent, and even pieces of stratified rocks—and are therefore called *fragmental*; the purely lava rocks, on the other hand, consist of *original* matter brought up from the interior of the earth, and are called *crystalline*.

When a rock is said to be crystalline it means that the minerals of which it is composed are in the form of *crystals* (fig. 55). The crystals are formed in the rock as the molten matter cools from the liquid to the solid state. We can obtain a good idea of the crystallization of substances if we dissolve some alum in about twice its weight of hot water, and then allow the solution to cool. The crystals of alum form on the sides of the vessel containing the solution, or on any substance, as a piece of thread or stick, immersed in the latter. Similarly, we can obtain crystals from melted solid

CHAPTER XIV

FORMATION OF ROCKS—(*Continued*)

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being a substance which results from the rapid cooling of fused matter; and in the latter case, to see the crystals we require to prepare thin sections of the rock and examine these through a microscope.

Now, as has already been pointed out, lavas which reach the surface cool more quickly than those which do not, and consequently the rocks formed from them are either glassy or have their crystals smaller and less perfectly formed than the rocks derived from the deeper-down material. This is shown in the case of basalt and granite, the rocks already mentioned, the former having resulted from molten matter which reached the surface, or approached very near to it, and the granite from that which remained deep down in the earth and did not come to the surface. The lava forming the granite therefore cooled more slowly and under greater pressure than that from which the basalt was derived. The crystals of its minerals, namely, quartz, felspar, and mica, are accordingly larger than those of the minerals of which basalt is composed, and at least the felspar and mica crystals are visible to the naked eye (fig. 56). To see the crystals of basalt we usually require the aid of a microscope.

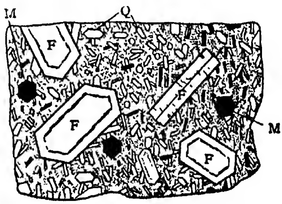


Fig 56 — Polished Surface of Granite

F, Crystals of felspar; Q, crystals of quartz; M, crystals of mica.

A rare but perfectly glassy form of basalt is known as *tachylite*. It is produced by the sudden cooling of the molten basaltic matter in contact with rock, hence is sometimes found occurring as a thin crust on dykes (§ 71). In another form, called *dolerite*, the cooling of

the molten rock matter has gone on comparatively slowly, and the crystals are consequently to be seen by the unaided eye. Thus we have three varieties of the same rock, the differences in their texture being due to variations in the rate of cooling of the molten rock matter. Basalt and dolerite are heavy black rocks, and are very common in Britain.

In connection with the formation of granite from molten matter which remained deep down in the earth, we must note that the present position of large masses

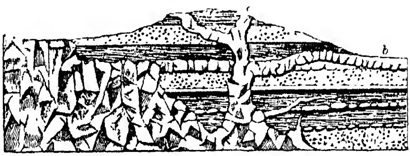


Fig 57.—Igneous Rocks, *a*, *c*, *b*, breaking through and intruding on Stratified Rocks The igneous rocks at *c* break through the sandstones, shales, &c., nearly at a right angle, but the intrusive band *b* has forced its way laterally, and lies almost parallel to them

of this rock on the surface of the earth, and even forming parts of mountain chains, is due to elevation of the earth's crust and to denudation.

70. **Igneous Rocks not Stratified and Unfossiliferous.**—Now in relation to igneous rocks we must notice that they do not occur in regular beds or layers like coal, sandstone, &c., but in huge irregular or shapeless masses (fig. 57), often standing high above the general level of the country. For this reason they are termed *unstratified rocks*, in contradistinction to coal, shale, &c., which we know are called *stratified rocks*.

Sometimes volcanoes occur under the sea (hence termed *submarine volcanoes*), and the material discharged from these, as well as the dust, ashes, &c.,

which reach the sea bottom from land volcanoes, become covered over with deposits and thus may form beds; but these are easily distinguished from the regular stratified rocks.

Again, except for the remains of trees, animals, and fish sometimes found in the volcanic ash, igneous rocks contain no fossils, hence are sometimes called *unfossil-*

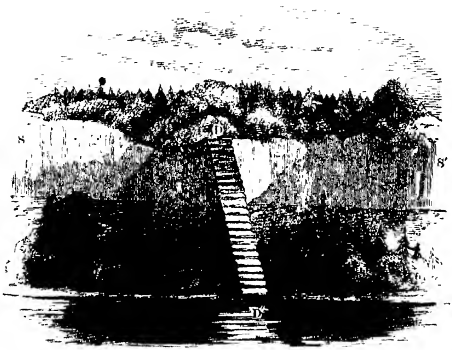


Fig 58.—Dyke of Igneous Rock, DD' (Basalt), traversing Sedimentary Strata SS'

iferous rocks, the stratified rocks, which we have seen to contain fossils, being known as *fossiliferous rocks*.

71. Dykes and Intrusive Sheets or Sills.—We must now consider what are known as *dykes* and *intrusive sheets* or *sills*. These are of great importance from the mining point of view.

A *dyke* (fig. 58) is a wall-like mass of solidified igneous matter found cutting up through other rocks. It has been formed by the molten lava, when the volcano

was in action, forcing itself up through the breaks in the rocks and afterwards cooling down and solidifying.

Dykes are more or less vertical and descend to unknown depths. They sometimes terminate before reaching the surface, but when they appear there, being harder than the surrounding rock, and therefore less subject to the effects of denudation, may be found standing several feet above the latter. Hence their name, "dyke" (or "dike") being the common Scotch word for wall. Some dykes are only a few feet in length; others

Fig. 59.—Intrusive Sheet of Basalt (a, a), which has altered the Sandstone Bed (b) above it, and also the Bed of Shale below it

run across the country for miles. They also vary in thickness, from less than 1 ft. to more than 100 ft.

Intrusive sheets or sills are masses of igneous rock occurring between the stratified rocks (figs. 57, 59). In this case the molten matter has thrust or *intruded* itself along the junction of the beds of sandstone, shale, &c., and there solidified in the form of sheets or layers.

Intrusive sheets or sills are more or less parallel to the stratified rocks between which they occur; sometimes they send off veins or shoots into the latter.

Other Names for Dykes, &c.—As has been seen, a common name in some districts for any hard rock such as basalt is "whinstone" or "whin". Miners therefore speak of "whin dykes", and "whin floats", the latter term signifying a sill or intrusive sheet. Often the

words "whin" and "float" are used alone, the former term being employed to denote any very hard mass, as distinguished from the regular rocks, which are usually only comparatively hard. "Float", of course, always means a "sill".

72. **Effect of Dykes, &c., on the Stratified Rocks.**—As might be expected, the effect of dykes on the stratified rocks through which they pass is usually very marked. Owing to the great heat of the molten mass the strata on each side of the dyke are baked and altered. Limestone, for example, is changed into marble, sandstone into a hard rock known as "quartzite", and shale into hard slaty rocks, while coal may be so "burnt" as to be nothing but a cindery mass.

Sometimes the outer parts of the igneous mass itself, where in contact with coal, undergo alteration, being found to be less hard and of a whitish or yellowish colour. Miners then sometimes apply the names "white rock", "white trap", and "white horse".

Sills or sheets have a similar effect to dykes. They may be found above or below the seam, or even spread through the coal itself, with the result that the latter may be so burnt as to be quite unfit for use.

73. **What a Mineral is.**—Before concluding the present chapter it will be well to see what a mineral is, and at the same time to note one or two other points in connection with stratified and igneous rocks.

A mineral, then, is any natural substance which is of the same composition throughout, and is neither of animal nor vegetable origin. It is therefore an *inorganic* substance (i.e. *not* an *organic* substance, or not formed from the organs of plants or animals). Accordingly coal and limestone are not true minerals, both of these rocks, as has been seen, being organically derived. Generally, however, they are called minerals, as indeed

is any natural substance of commercial value found in the earth. But it is well to note what a *true* mineral is.

Quartz, felspar, and mica, which we have seen form granite, are true minerals, and similarly all the crystalline igneous rocks are composed of true minerals. The total number of true minerals is very great, but only very few enter largely into the composition of rocks. Thus the great mass of the earth's crust is made up of less than a dozen minerals. The science which treats of minerals is called *mineralogy*, and is a very important branch of geology. Persons skilled in mineralogy are termed *mineralogists*.

Quartz, felspar, and mica are common rock-forming minerals, but the most abundant of all is quartz, as, besides being present in granite and certain other rocks, it forms the greater part of sand and sandstone. This is shown by examining, through a microscope, specially prepared sand, obtained either from the seashore or by gently powdering a piece of sandstone. The grains of prepared sand are then seen to be for the most part colourless, and to consist of broken pieces of quartz crystals. Particles of mica may also be detected.

But if we reflect for a moment we can see that the presence of quartz and mica in sand and sandstone is only what is to be expected. The sedimentary rocks, as we have learnt, are formed from the fragments of other rocks, and the particles which go to form them must therefore be derived from both igneous and stratified rocks. The stratified rocks make up almost the whole of the earth's crust, the igneous rocks breaking through them in the way shown in the present chapter, and occurring mostly in mountainous districts, yet, as we shall see in the next chapter, the first stratified rocks are believed to have been formed entirely from the denuded material of igneous rocks.

CHAPTER XV

FORMATION OF ROCKS—(*Continued*)

The Earth Very Old—Early Condition—Determination of the Relative Ages of Rocks—Order of Succession of Strata.

74. **The Earth Very Old.**—So far as is necessary for our purpose we have now seen how rocks are formed (chap iv), and it is evident that to build up any of the beds in the earth's crust must have involved a very long interval of time

In the case of sandstone and shale the material, as we have seen, had to be carved out of the solid land, ground down where necessary by the action of water, and finally converted into rock at the bottom of the sea. In the case of limestone the little animals, about which we learnt in chap. x, had to live and die, and their skeletons, or hard parts, be piled up in countless millions on the sea floor.

Then to form each coal seam generation after generation of plants had to rise and fall; and, quickly as all kinds of vegetation may have grown in those days, we cannot imagine whole forests to spring up and die in brief spaces of time.

And the growth and death of the great coal-forming forests was not all that was required. The ground, we know, had to sink, and the vegetation be covered over with the masses of mud and sand produced from the solid land that remained.

This brings to our minds the immense periods of time that must have elapsed during the formation of the various coal seams and intervening strata to be found in some districts, the processes of the growth and decay of the plants, the sinking of the land, and the

deposition of mud and sand, &c., having to be repeated, as we learn in chap. ix, in the case of each one of the seams. In a single coalfield as many as fifty to over a hundred seams may be found occurring one above another, with their beds of shale, sandstone, &c., between.

Then what ages must have passed since the coal-bearing strata came into existence. Many millions of years must have gone by, though that does not tell us much—a million being such a large number our minds are unable to grasp its true significance.

And, ancient as the coal-bearing strata are, we must not think they are the oldest beds in the earth's crust. As we saw in chap. ii, the making of the rocks forming the exterior part of the earth has gone on at all periods, and geologists are aware that there are many beds which must have come into existence ages and ages before those containing the coal seams.

Truly, then, the earth must be very old—how old no one can tell, but certainly many millions of years—and knowing this we are perhaps less surprised at the vast changes it has undergone.

75. **Primitive or Early Condition of the Earth.**—Now in chap. iii we learnt as to the temperature of the interior of the earth, and that geologists believed the whole earth to have been at one time much hotter than it is at present. It may now be said that they believe the earth to have been once nothing but a great, glowing, molten globe or ball. At that time, of course, there could be no rocks, no air, and no sea. The great glowing ball, however, contained everything necessary for the formation of these, and when it had cooled down sufficiently the hard solid surface of the earth was formed and the sea and air came into existence. Hence it is, it is thought, that the interior of the earth is still intensely hot, the rocks near the surface representing

the part that has cooled and the inner part that which has not yet lost its heat.

Also, it is now clear to us that the first rocks formed in the earth's crust must have been igneous ones, having cooled down and solidified from a molten state. Afterwards, air and water being then present on the earth, the igneous rocks would begin to be worn away and the stratified rocks to be formed, the making of the latter continuing up to the present time. The earliest sedimentary rocks would be formed entirely from the remains of igneous rocks, the materials of subsequent sedimentary rocks being derived from all kinds of previously existing rocks. It must be remembered, however, that what is stated here in regard to the origin of the earth is merely a "guess at truth", and that geologists are not agreed on this question.

76. **Determination of the Relative Ages of Rocks.**—Now geologists, though they do not know the actual ages of the beds of rock in the earth's crust, as was stated in chap. ii, can tell their *relative* ages, or what beds were formed before other beds. This they are enabled to do by considering the position of the beds, the fossils they contain, their mineral characters, and any fragments of other rocks found in them.

Though very interesting, it is not necessary for us to study the subject very fully, and therefore it will be sufficient to say (1) that wherever two beds of rock are lying in their natural position (that is, as they were formed, not inverted, and not overlapping, as in the case of reversed faults), whether they are horizontal or inclined, then the bottom bed is always the older; (2) that the beds of rock produced in one period of time contain different fossils to those produced in another period of time, and also (3) have usually special mineral characters of their own; (4) that a rock containing fragments of another

rock is younger than the rock whose fragments are enclosed in it.

The question of the fossils is a most important one. In chap. ix we saw what these are—the remains, or traces of the remains, of once living plants or animals found embedded in the earth. When the plants or animals died their bodies became buried in the soft rock-forming material, and so we find locked up in the rocks either the actual remains of the plant or animal or such traces or copies of them as enables us to realize what the once living organism was like.

The fossils, then, are the evidence we have of the kinds of living things that have existed on the earth in past times. Of course very few of the plants and animals that lived in past ages have been preserved in the form of fossils, but by carefully examining and studying such fossil remains as have been discovered it has been found that the earliest form of life was of a lowly type, and that as time went on the living things on the earth became gradually of a more advanced or higher form until man appeared, which was not, we should observe, till long after the coal-forming period.

77. **Order of Succession of Strata** (or order in which the stratified rocks were deposited).—So we can now understand how it is that by means of the fossils, aided by the other tests mentioned in the last section, geologists can tell the comparative ages of rocks, and, in imagination, are able to arrange the beds in the earth's crust in the positions they would have occupied if they had been lying according to the time when they were formed and had never been subjected to upheavals and other movements, which, as we saw in chap. ii, would be the oldest beds, about 20 miles down, the next oldest on the top of these, and so on, up to the most recently formed beds at the surface. Referring only to the fossils,

we can see that since different kinds of things lived during different periods of time the beds of rocks formed during the various periods of time must contain different kinds of fossils, and that since the most primitive or lowly types of life come first these will be represented in the earliest formed rocks, the rocks of the succeeding period of time containing fossils showing a more advanced type of life, and so on, to the rocks of the latest period, the fossils of which should be indicative of plants and animals approaching those of the present day.

Now the periods or *eras* into which, as shown by the fossils, is divided the time which has passed since the stratified rocks began to form are three in number. Their names are: (1), the *Palæozoic*, or period of ancient life (from the Greek *palaios*, ancient, and *zoe*, life); (2), the *Mesozoic*, or period of middle life (Gr. *mesos*, middle, and *zoe*, life), and (3), the *Cainozoic*, or period of recent life (Gr. *kainos*, recent, and *zoe*, life). All the stratified rocks in the earth's crust are arranged into three corresponding *groups*, namely, the "Palæozoic group", containing all the beds formed during the Palæozoic period of time, the "Mesozoic group", all the beds formed during the Mesozoic period, and the "Cainozoic group", all those formed during the Cainozoic period.

Sometimes, instead of three, four or five periods of time and corresponding groups of rocks are chosen, but the division into three great periods and three great groups will suit our purpose very well. Sometimes, too, instead of the groups of rock being called "Palæozoic", "Mesozoic", and "Cainozoic", the terms *Primary*, *Secondary*, and *Tertiary* are used.

Now it is clear from what we have seen in the present chapter as to the time necessary for the formation of rocks, the Palæozoic group making up a thickness of

about 17 miles, and the other two groups together about 3 miles, that each of the great periods must cover an enormous interval. Great changes, then, must have taken place while each of the great groups of rocks was being formed, and so, for convenience, each of the great periods of time has been divided into smaller periods, and each of the great groups of rocks into smaller groups, the smaller groups thus formed being called *systems* or *formations*.

78. **Names of Rock Systems.**—On the opposite page are the names of the different systems or formations of rocks. They are arranged in a column, the name of the oldest formation being at the foot and that of the youngest at the top, to correspond with what we know would be the position of the beds had they been lying horizontally and according to the period when formed. It will be noticed that the formations or systems are also divided into still smaller groups called *series*, each series consisting of a number of beds.

We may compare the different formations to books, fifteen in number, and of different thicknesses, piled up one on top of another. The bottom book will represent the Pre-Cambrian and the top one the Post-Pliocene formation. The complete pile of books will stand for a thickness of strata equal to about 20 miles, the seven volumes nearest the base indicating a thickness of about 17 miles, and the other eight a thickness of about 3 miles.

This arrangement of the books, one on the top of the other, would represent the formations in the order of their age, or period of time in which they were formed, but we are aware that the beds are not lying in the earth's crust as indicated by the pile of books. If they were, then it is quite plain we should know nothing of the rocks farther down than about a mile, and, there-

Names of the three GREAT PERIODS or ERAS into which the time which has passed since the stratified rocks began to be formed is divided, and of the three GREAT GROUPS (formed during, and corresponding to, the periods of time) into which all the stratified rocks in the earth's crust are arranged	Names of the smaller periods of time (but yet very great) into which each of the three great periods or eras is divided, and of the FORMATIONS or SYSTEMS (formed during, and corresponding to, the shorter periods) into which the great groups of stratified rocks are divided	Names of the STILL SMALLER GROUPS or SERIES into which each of the formations is divided (shown only in the case of three formations).
3. Cainozoic . . .	Post-Pliocene	Recent strata, consisting of river gravels, alluvium, &c. Glacial deposits, consisting of boulder clay, &c.
	Pliocene.	
	Miocene.	
	Oligocene.	
	Eocene.	
	Cretaceous.	
2. Mezozoic . .	Jurassic.	
	Triassic.	
	Permian . .	Magnesian Limestone. Permian Sandstone.
	Carboniferous .	3. Coal Measures. 2. Millstone Grit. 1. Carboniferous Limestone.
1. Palæozoic . . .	Devonian or Old Red Sandstone.	
	Silurian.	
	Ordovician.	
	Cambrian.	
	Archæan or Pre-Cambrian.	

fore, nothing of the Carboniferous system, which is the system in which coal seams principally occur.

But, as was stated in chap. ii, the rocks have been upheaved and subjected to the action of denudation, and therefore they appear at the surface, where geologists can see and can examine them. And, as we saw in

chap. ii, it is from their observations at or near the surface that geologists have acquired all their information concerning the rocks of the earth's crust.

The different formations, then, are to be seen at the surface, and if we wished to arrange the books more in the true positions of the formations, then we would need to place them on their edges or backs and sloping in such a way that the volume representing the Cambrian would lean or rest on that denoting the Archæan, that indicating the Ordovician on the one standing for the Cambrian, and so on, to the volume denoting the Post-Pliocene, which would lean or rest on the one representing the Pliocene system. In this case the leaves of the books would denote the outcropping edges of the strata (see also fig. 60).

The arrangement of books helps us to realize the position of the various formations with respect to one another, but we must keep in mind the vast difference between the row of books representing the formations and the systems themselves. Thus some of the latter are thousands of feet in thickness, they are not so parallel to one another as are the books (fig. 60), and one or more of them may be locally missing.

CHAPTER XVI

FORMATION OF ROCKS—(*Continued*)

Absence of Formations—Importance of a Knowledge of the Order of Succession—Geological Maps—Fossils—The Carboniferous Formation—Unconformities.

79. **Absence of Formations.**—In the preceding chapter we learnt as to the general succession or order of sequence of the stratified rocks; and in the concluding

paragraph saw that one or more of the formations might be locally missing. Now although a formation may happen to be wanting in a particular locality, that does not affect the order of succession of the formations, the system above the one missing then merely resting on the one next below, or on an older formation than would be the case if all were present.

Thus, for example, if the Carboniferous system were missing we might find the Permian resting on the Devonian, but not the Devonian on the Permian. If both Carboniferous and Devonian were absent, then the Permian rocks might be found resting on the Silurian, but not the Silurian on the Permian. And similarly in all other cases, the older formations, under ordinary circumstances, always underlie the newer and not the newer the older. We may illustrate this by removing one or more of the books from the arrangement representing the formations.

80. **Importance of a Knowledge of the Order of Succession.** – In relation to the question of the presence or absence of a formation, a general knowledge of the order of succession of the strata is of great practical importance. Thus the Carboniferous system being the one in which coal principally occurs, if we found, say, Permian strata at the surface. knowing it overlies the Carboniferous, we might conclude that coal would be found below. But we see from the present chapter that the Carboniferous rocks might be wanting, and therefore we should require to take steps to prove that this system existed. Similarly with all other formations newer than the Carboniferous, because we know that under ordinary conditions they occur higher up than the coal-bearing strata we must not take it for granted that the latter are to be found under them. On the other hand, if the formation at the surface were *older* than the Carbon-

iferous, then from the order of superposition (unless in the case of inversion, § 76) we should conclude that the Coal-measures strata were not to be found below.

Fig. 60.—Section from West to East, showing the succession and general arrangement of the stratified rocks in Wales and part of England

1, Archæan, 2 Ordovician and Silurian; 3, Old Red Sandstone; 4, Carboniferous or Mountain Limestone, 5, Millstone Grit and Coal-measures; 6, Permian; 7, 8, 9 and 10, Secondary rocks, 11, Tertiary rocks

81. **Geological Maps.**—We can see then that it is important to know about the different rocks that appear at the surface; and the maps termed *geological maps* (§ 52) have been specially prepared to supply the required information. These show the outcrops of the strata in stripes of colour, indicating at a glance the formations which occur in different districts.

On the geological maps diagrams of horizontal sections are given which, as we have learnt, show the general arrangement of the strata in the districts to which the sections apply. A horizontal section is shown in fig. 60.

82. **The Discovery of Fossils as a Means of Determining the Ages of Strata.**—Now, considering that a geologist's knowledge of the rocks forming the earth's crust has to depend on what he sees at the surface, and considering the many other difficulties to be overcome, finding out the relative ages of the rocks must be regarded as a truly wonderful feat. It only became possible when William Smith, a land surveyor, now spoken of as the "Father of British Geology", made the discovery as to the fossils, explained in § 77.

It was while Mr. Smith was engaged as an engineer

in the cutting of the canal between Bath and Bristol that he noticed different kinds of strata had their own peculiar fossils, and this led him to the conclusion that the fossil contents of rocks could be used as a means for their identification. This illustrates to us the great importance of observation and thought in connection with the subjects of our daily employment.

83. **Uses of Fossils.**—But forming "links with the past", in respect of showing us the different types of life that have existed in former times, and aiding in the determination of the ages of strata, are not the only uses of fossils. By their means geologists can tell whether the rocks were produced at the bottom of a sea or lake, or in brackish water; whether the water was deep or shallow, and also what was the climate of the period.

84. **The Carboniferous Formation.**—This, being the formation in which coal chiefly occurs, is the one in which we are principally interested. Seams of coal are found in other systems, but the richest and most abundant coal deposits are contained in the Carboniferous system.

The name of each formation has a special meaning or has been given for a particular reason, and "Carboniferous" signifies "carbon-bearing" (L. *carbo*, coal, and *fero*, I bear). Carbon, we saw in chap. xi, is the chief constituent of coal, but it is also one of the substances which go to the formation of limestone, and is contained in some shales. It is evident, then, that the amount of carbon present in this particular formation must be very great, and that the name "Carboniferous" is well bestowed.

The Carboniferous system is well developed in the British Isles. It varies greatly in different districts both in regard to the thickness and the nature of its strata; and no list of beds (or general succession of strata) can be given as applying to all localities. This

will be understood by considering the conditions which prevailed during the period; first, however, the series, as shown in the table of formations (§ 78), should be again examined (see also fig. 60).

85. **Conditions of Deposit of the Carboniferous Rocks.**—From the evidence afforded by the rocks and fossils it is believed that at the time the beds forming the system began to be laid down most of the area now occupied by the British Isles was below sea level. The sea was deep towards the south, shallowing towards the north. Its floor consisted of a sandstone called the *Old Red Sandstone* (§ 78), to distinguish it from another sandstone termed the *New Red Sandstone*, which was formed in the period of time after the Carboniferous. On the deep part of the sea floor a bed of limestone was formed—the *Mountain Limestone* we read about in chap. x. Because it was formed in the Carboniferous period it is also called the *Carboniferous Limestone*.

After a time the sea bottom, it is believed, began to be elevated, and in the shallow sea thus formed a coarse sand was deposited—of course on the top of the limestone. The series of coarse sandstone beds resulting from this sand is termed the *Millstone Grit* (§ 78). Because the miners in South Wales knew that when they reached the Millstone Grit they might abandon all hope of finding coal, it has long been known as the "farewell rock". But this must not be taken as applying to all districts, coal seams being found in the Millstone Grit in the north of England and both in and under it in Scotland. The Millstone Grit is so called because millstones were made from it. Other names sometimes used are "rough rock" and "moor rock".

The sea now became filled up, and in the swamps and marshes thus formed the coal-forming vegetation grew, just as we learnt in chap. xi.

The strata containing the coal seams are called the *Coal Measures* (§ 78), and, as we have seen, consist of great thicknesses of shales and sandstones, with beds of coal, underclay, and sometimes ironstone and limestone. The thickness of the Coal-measures strata varies greatly in different coalfields. In Scotland it is about 2200 ft., in Northumberland and Durham about 3000 ft., in Lancashire about 6000 ft, the maximum being attained in South Wales, where the thickness is nearly 12,000 ft.

Changes in the Carboniferous Strata.—We see, then, from the conditions of deposit of the Carboniferous rocks, that changes in the character of the beds, as we pass from one district to another, are no more than is to be expected Thus, while the Mountain Limestone was being laid down in the more southern districts of England, deposits of sand, &c., would be taking place in the shallower seas of the north, and therefore, in place of the limestone in the south, we get in the north sandstones and shales, with beds of coal and ironstone, and only occasional beds of limestone. In Scotland the conditions of deposit were different, and we find coal seams both above and below the Millstone Grit, some of the latter seams being contained in the Carboniferous limestone and some under it.

86. **Formation of the Coal Seams into Basins.**—It must now be explained why the coalfields of Britain occur in the form of "basins", § 4. It is believed to be due to elevations of the earth's crust and to denudation.

As is evident from the extent of the coal-bearing strata in different countries, the vegetation from which coal resulted must have grown in great profusion all over the world. In the British Isles coal seams are believed to have been formed over the southern half of Scotland and most of England and Ireland. The existing coalfields, then, represent only a portion of the original coal-bearing area.

Now, at the end of the Carboniferous period vast earth movements seem to have taken place. The rocks, including the coal seams, were forced into great folds or earth wrinkles. Some of these (like the Pennine Range) ran north and south, and some (like the Mendip Hills) east and west, the two sets thus crossing one another. Thus the strata containing the coal seams were thrown into a series of elevations and depressions of basin shape, and the tops of the folds, becoming worn away in the course of time by the action of the various denuding agents, only the Coal measures in the basins were left.

87. **Industrial Products of the Carboniferous System.**—No system is so rich in mineral deposits as the Carboniferous. The most important products are, of course, the coal, ironstone, and limestone. Sometimes beds of ironstone are worked as separate seams, and sometimes a bed or layer occurs associated with a seam of coal, so that the two can be extracted together. The limestone is burnt into lime, and is also used with the coal and iron ore in the making of iron. The proximity of these three substances—coal, ironstone, and limestone—enables iron to be produced more cheaply than when one or more of them has to be conveyed a long distance.

Ores of lead, zinc, and antimony are found in the limestone rocks in some districts.

The underclay occurring in coal seams is used for making such articles as firebricks and crucibles, which will withstand great heat without melting. For this reason it is generally called *fireclay*. Sometimes the name "seggar-" or "saggar-clay" is used, because the "saggars" in which the porcelain is burnt are made of it. A bed of good fireclay occurring with a thin seam of coal may enable the latter to be worked cheaply and profitably.

A hard, close-grained variety of fireclay, called *ganister*, found chiefly in the north of England, is possessed of great heat-resisting powers. It is made into bricks for lining furnaces, &c., where great heat is given off.

The sandstones are valuable for building and other purposes, while some shales are mined for the manufacture of mineral oils, others being used in the preparation of alum.

88. **Unconformity.**—When one set of stratified rocks

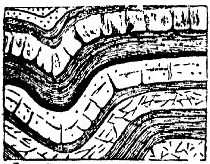


Fig 61 —Conformable Strata. All the rock beds are parallel and therefore conformable to one another, although on the left of the diagram they are contorted

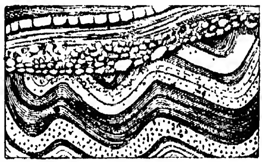


Fig. 62 —Unconformable Strata. The lower set of beds were disturbed and bent into folds before those above them were deposited. A conglomerate band is seen at the junction

is laid down regularly on the top of another set the strata are said to be *conformable*. The newer rocks "conform" to the older, the beds of the two sets being parallel and having the same dip (fig. 61). Sometimes, however, the newer rocks are found to rest on the denuded edges of the older (fig. 62). In this case the newer rocks evidently do not conform to the older, the strata accordingly being said to be *unconformable*, and the arrangement of the beds termed an *unconformity*. In the case of an unconformity the older set of rocks must have been upheaved, subjected to denudation, and then again submerged before the newer beds were deposited.

An unconformity, then, denotes the passage of a long interval of time between the formation of the two sets of rocks. We can illustrate unconformity by arranging books as explained in § 78, and then placing other books on their sides on the upturned edges of the row. It is also possible to have an unconformity in which the newer beds are parallel with the old.

Unconformities are frequent between many of the systems or formations. Sometimes, too, the smaller groups or series into which a formation is divided are found resting unconformably on another series of the same formation. Then great unconformities exist between each pair of the three great groups of rocks, between Primary and Secondary and between Secondary and Tertiary, these great unconformities and the changes in the fossils marking off one group from another.

CHAPTER XVII

FORMATION OF ROCKS—(*Continued*)

Aqueous, &c., Rocks—Cleavage—Jointing—Fossils

We have now reached the last chapter in the more purely geological part of our subject—the part by the study of which we have been enabled to learn not only what coal is, and how it comes to be buried in the ground, but also concerning "many other things", all, as was stated, "necessary to make the whole matter very plain". The present chapter will deal with such matters regarding the rocks already considered as it was impossible to include in the previous ones, and will be partly revisal. It will also treat of other rocks of which, as mentioned in chap. iv, it is desirable to have a little

nowledge. Then the part of our studies which relates o geology terminating with the present chapter, chap. viii will see the commencement of the more distinctly ining part, though here also, as in our past work, t will be necessary to go off into interesting side tracks o pick up information which will assist us in travelling long the main path of our journey.

89. **Aqueous Rocks.**—In §46 we saw that shale, sandtone, and conglomerate are called "aqueous rocks" beause they have been formed under water or by the ction of water. For the same reason coal and limetone must also be regarded as aqueous rocks. All hese rocks we know are termed "stratified rocks" §46).

90. **Mechanically-formed Rocks.**—Limestone and coal, s has been seen (§48), are called "organically-derived" r "organically-formed" rocks, and shale, sandstone, and onglomerate, as also are clay and sand, "sedimentary ocks" (§46). It is worth while noting that clay, sand, hale, sandstone, conglomerate, and also a rock termed *reccia*, are sometimes given the name *mechanically-ormed rocks*, because formed by purely mechanical neans from the remains of other rocks.

91. **Argillaceous and Arenaceous Rocks.**—Then the nechanically-formed rocks are sometimes subdivided nto classes, according as they contain much clay or and, those which are composed entirely or largely of lay, as, for example, clay and shale, being termed *argillaceous rocks* (L. *argilla*, clay), and those, such as sand, ravel, sandstone, conglomerate, and breccia, which are nade up of sand or are of a sandy nature being called *renaceous rocks* (L. *arena*, sand).

92. **Calcareous and Carbonaceous Rocks.**—Similarly, the rganically-formed rocks are subdivided into *calcareous ocks*—those composed of limestone or containing limy

matter (L. *calx*, lime)—and *carbonaceous rocks*—those, such as peat and coal, which contain much carbon.

93. **Mud and Clay.**—We have seen how mud and clay are produced from the solid land by the various denuding agencies. All rocks being made up of minerals or mineral matter, mud and clay consist of fine particles of mineral matter, the particles in the case of clay adhering together. Mixed with the mineral matter of mud may be particles of animal and vegetable substances.

The purest kind of clay is known as *kaolin* or *china clay* (or *porcelain clay*), and is obtained from granite as the result of the decomposition of the felspar. It is white in colour. Common clay is clay mixed with various impurities. The chief impurity is sand. It is the presence of impurities in clay which gives it its red, brown, blue, &c., colour.

94. **Shale** (§46) is compressed or hardened mud or clay which splits up along the lines of stratification into thin layers or plates, called *laminæ*. Rocks which split up in this way are said to be *laminated*, the lamination showing that they have been gradually deposited under water. Shales are often dark in colour, owing to the presence of vegetable matter. Oil shale (§87), sometimes termed *bituminous* and *carbonaceous shale*, contains much carbonaceous matter. It is of a dark-brown or black colour.

Beds of shale or shaly rocks are given different names by miners, as, for example, *bind*, *blue-bind*, *blaes*, *bass*, and *batt*, the two last-mentioned being applied to shales black in colour in consequence of their containing much carbonaceous or vegetable matter. When there is much sand present, forming a sandy or arenaceous shale, the terms *stone bind* and *rock bind* are used.

95. **Loam** is a soft mixture of clay and sand. The presence of sand renders it pervious to water.

96. **Marl** is a mixture of clay and lime. It is therefore sometimes called "calcareous clay" (§ 92).

97. **Sandstone.**—Different names are given to sandstone according to the nature of the cementing agent (§ 46). Again, when a sandstone is made up of coarse particles it is termed a *grit* (§ 85). When it splits easily into layers it is called *flagstone*, the slabs obtained in this way being used for "flagging" or paving the sidewalks of towns. Sandstones usually contain mica (§ 73), and when the flakes are spread along the planes of bedding the rock splits very easily into slabs. Sandstones containing much mica have a glittering appearance and are termed *micaceous sandstones*. *Freestone* is sandstone which has no tendency to split in one direction more than another, and can therefore be cut easily into blocks suitable for building purposes.

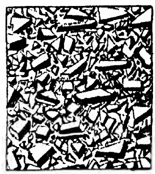


Fig. 63 – Breccia, consisting of angular fragments embedded in a matrix

98. **Breccia** must be carefully distinguished from conglomerate (see figs. 63 and 29). Like conglomerate it consists of rock fragments held together by some natural cementing agent, but the fragments of breccia are *more angular* than those of conglomerate, showing that they have not been subject to much water action. For *fault breccia* see § 63.

99. **Coal.**—Besides carbon, hydrogen, oxygen, and nitrogen, coal contains earthy substances, these forming the *ash* which remains when the coal is burnt. Ash, like sulphur (§ 62), is an undesirable substance in coal, being incombustible, and therefore the smaller proportion of ash the more valuable is the coal.

In § 58 coal was divided into *lignite*, *common coal*, and *anthracite*. Lignite burns with little flame, and with

an odour like that of peat. Common coal is sometimes termed *bituminous coal*, and includes *caking* and *non-caking coal*. *Caking coals*, when burning, fuse and swell, uniting into a pasty mass. They are used for making *coke*, and for this purpose are put into an oven, termed a *coke oven*, and heated up to a certain temperature. The resulting greyish-looking substance is the coke. Coke is valuable for different purposes on account of the intense heat which it gives off when burning, and its freedom from smoke. Some caking coals make good house coals.

Non-caking coals do not cake together, hence are sometimes termed "free-burning coals". Varieties are *house coal* and *steam coal*. For household purposes coal which ignites easily and gives off much heat, burning with a bright flame and little smoke, and leaving little ash, is preferred. Steam coals give off great heat and little smoke.

Gas coals are those used for the production of coal gas. They contain much hydrogen. The best example of gas coal is that known as *cannel coal*. Cannel coal is sometimes carved into ornaments. A name given to this coal, in consequence of the crackling noise made by it in burning, is "parrot coal".

Anthracite, sometimes termed *stone coal* and *blind coal*, is heavier than bituminous coal, and is jet black in colour. It is difficult to ignite and burns without flame, but with intense heat and practically no smoke.

100. **Chemically-formed Rocks.**—A third class of aqueous rocks are known as *chemically-formed* rocks. Examples are *stalactites* and *stalagmites* and the rock material deposited at the mouth of some springs (§ 21). Other chemically-formed rocks are *rock salt*, found in beds in Cheshire and other places, *flint*, found in nodules or lumps in chalk and other limestones, *gypsum* and *dolo-*

mite (or magnesian limestone, § 78). Gypsum, like dolomite, is a limestone. Thus we have chemically-formed limestones in addition to those derived from the organs of animals. *Alabaster* is a variety of gypsum.

101. **Ironstone**, we saw in § 87, is sometimes found associated, and worked, with coal. *Clay-ironstone* consists of a substance called "carbonate of iron" mixed with clay and carbonaceous matter, and occurs in nodules and layers or bands. It is sometimes called "clayband" ironstone. *Blackband ironstone* is clay ironstone containing a considerable proportion of carbonaceous or coaly matter. Other iron ores are *magnetite* or *magnetic iron ore*, *hæmatite*, and *bog iron ore* or *limonite*.

102. **Metamorphic Rocks.**—These are altered aqueous or igneous rocks, hence the term *metamorphic* (Gr. *meta*, change, and *morphē*, form)

Examples of aqueous rocks which have thus undergone change are *shale, sandstone*, and *limestone*, shale being altered into *slate*, sandstone into the crystallized rock known as *quartzite*, and limestone into crystallized limestone or *marble*. The change (or *metamorphism*) may take place deep in the ground, where we know the rocks are subjected to very high pressures and temperatures (chaps. ii and iii), but, as has been seen, may also occur as the result of the passage of molten lava through the rocks (§ 71). Metamorphism is also brought about by the chemical action of water percolating through the pores and fissures of the rocks.

Another example of a metamorphic rock is *gneiss* (a German miners' word). This rock has the same minerals as granite, but arranged in layers instead of being scattered through the mass as in the case of granite.

For this reason gneiss is called a *foliated rock*, rocks which have their minerals arranged in layers or leaves being termed *foliated* (L. *folia*, leaves; fig. 64). Other

foliated rocks are known as *schists* (Gk. *schizo*, to split), as *mica schist*, consisting of alternate irregular leaves or layers of mica and quartz, in which the mica predominates, and *quartz schist* of layers of quartz and mica, in which the quartz is the chief mineral. A metamorphic rock of a greenish or brownish colour, but often so beautifully variegated as to resemble the markings on a serpent's skin, is called *serpentine*.

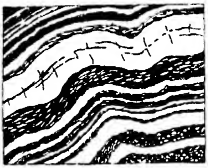


Fig. 64 – Foliated Structure in Rocks

103. **Cleavage.**—Cleavage in geology means the tendency, possessed by many rocks, to split into thin parallel layers along a direction which usually crosses the planes of bedding at some angle (fig. 65). It is well seen in slate, and is also known as *slaty cleavage*. Slate, we know, is altered shale. Now shale is a "laminated rock", splitting into thin layers or laminæ *parallel to* the planes of bedding (§ 94). Slate, however, splits in a direction which is *quite distinct from* the planes of bedding (fig. 65), and this is called cleavage. Cleavage is the result of pressure acting on the rock after it has been deposited, and forcing the particles to rearrange themselves with their longer direction parallel to the cleavage planes or at right angles to the direction of the pressure.

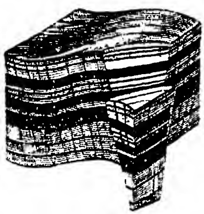


Fig. 65 —Cleavage The horizontal bands (or "stripes") show the bedding or stratification, the fine lines (nearly vertical) indicate the direction in which the rock "cleaves".

104. **Jointing.**—Nearly all rocks are traversed by sets of natural fissures or cracks called *joints*. In bedded

rocks the joints are generally at right angles to the planes of bedding, and thus, if the bed is horizontal, the fissures will be vertical. Usually there are two sets of fissures, but one set is generally better developed than the other. They cross each other at right angles, dividing, with the planes of stratification the rock into large cubical masses, and assisting in the quarrying of the stone. Jointing can therefore be seen in quarries. The joints dividing the rocks in the way described are sometimes termed "divisional planes". Sometimes to the better developed set of joints the name *master-joints* is given.

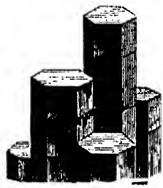


Fig. 66 – Columnar Basalt, from the Giant's Causeway, Ireland

Jointing is well shown in coal, and is of great aid in the working of the seam. In coal mining the name *cleat* or *face* is applied to the better developed set of joints, and the term *end* or "end cracks" to the less perfect set; hence miners speak of working the coal "on the face" and "on end". We shall learn further as to this in chap. xxiii.

Jointing, it is thought, may have resulted in some cases from the movements of the earth's crust, and in others from the contraction of the rocks in drying or cooling. A peculiar form of jointing is the columnar structure of basalt as found at the Giant's Causeway on the coast of Antrim, and Fingal's Cave, in the island of Staffa (fig. 66).

105. **Fossils.**—We have learnt a good deal in regard to these. It need, therefore, be only said further that when fossils are met with in working the coal care should be taken to obtain them unharmed. They should then be shown to some skilled person. Collections of fossils are to be seen in museums, and, if

necessary, any fossils found can be compared with these. The collection and identification of fossils is very interesting.

CHAPTER XVIII

PROVING THE EXISTENCE OF COAL

Starting a Colliery—Prospecting—Boring.

106. **Starting a Colliery.**—Before a colliery can be commenced, two things are evidently necessary, namely, *coal* and *men*. A third is *money*.

In regard to the *men* we need only note that the number employed at a modern colliery is frequently very large, and that while most are engaged in the actual process of excavating the coal (or "coal-getting", as it is often called), yet a considerable proportion are necessarily employed in the many and varied operations to which the working of the coal gives rise.

The charges for all labour at the mine, other than the coal-getter's wages, come under the general name of *oncost*, and all men employed in or about the mine, except those engaged at the cutting of the coal, are termed *oncostmen*. The coal-getter, or collier, is usually paid a certain sum for each ton of coal produced; if he receives any payment in addition to his rate per ton this also is termed "oncost".

The *money* is required to pay for the machinery, and for all work necessary until coal can be sent into the market. The sum required for these purposes is usually so very large, and the chances of loss are so great, since the seam may turn out unprofitable, that generally a number of persons combine together for the purpose, forming a "company".

Concerning the first item, Coal.—We know that it does not occur everywhere in a country, although the total amount of it stored up may be very great; and therefore, if it is desired to begin a colliery in any district, steps must be taken to make sure that coal exists.

But mere knowledge of the presence of the desired substance is not all that is required. Owing to the large sum involved in equipping the colliery, and in getting down to the seam or seams, endeavours have to be made to find out whether the quantity and the condition of the coal are such as will pay for the working of it. Then it is necessary that the coal should be produced and sent into the market at the lowest possible rates, and to assist in the attainment of these objects special information is required, and efforts must be made to obtain this information.

107. **Prospecting.**—In ascertaining whether the district is a coal-bearing one a knowledge of geology is of the utmost value. Persons skilled in geology, we have seen, are acquainted with the particular kind of rocks with which coal is usually associated, and can frequently tell from the appearance of the country whether coal is to be found. Many instances are on record of the discovery of coalfields by geologists in this way, where no coal was previously thought to exist; and it is also well known that large sums of money have been wasted by persons in trying to find coal in districts in which a knowledge of geology would have taught them that none could exist. (See also § 80.)

The search for coal is called *prospecting*, and the places examined are the sides of valleys, cuttings, quarries, and the banks and beds of rivers and streams. The great object is, if possible, to find the outcrop of a seam, and in the places named pieces of coal, shale,

or fireclay may be picked up, and lead to the discovery of this.

If the outcrop cannot be found, then additional precautions require to be taken to make certain that coal exists. A good sign is the discovery of fossils belonging to coal-bearing strata. Sometimes also the deposits at the mouths of springs are of value in affording evidence of the presence of coal, while the dark appearance of parts of the ground in freshly ploughed fields has been of direct service in the same respect.

If it is known, or believed, that coal exists, then we must endeavour to obtain the additional evidence required (§ 106). This will be as to the extent of the coalfield, the thickness of the seam (or seams, if more than one), the nature of the coal composing it, whether the seam is lying inclined or in a horizontal position, whether it contains faults, &c., the nature of the roof and pavement, the depth of the seam from the surface, and the nature of the strata that must be pierced to get down to it. To obtain information, so far as possible, regarding these points, *boring* is the method adopted, though, if the seam outcrops, the work is greatly simplified, and it may be possible to learn everything necessary by driving little passages or tunnels, called "drifts", into the coal, or by sinking small trial pits near to the outcrop.

108. **Boring.**—This consists in putting down a number of holes perpendicularly from the surface. Each hole is only a few inches in diameter. The total number bored depends on the depth of the coal, the extent of the field to be proved, and whether the ground is much "troubled". Usually, however, there are not fewer than three, though in some cases one or two may be considered sufficient. The holes, when more than two, are not generally put down in a straight line, but in such positions as will best prove the ground.

There are different methods of boring, but the two best known are the *ordinary* and *diamond* systems. Figs. 67–76 illustrate the tools and appliances used in the "ordinary" method. In this system the ground at the bottom of the hole is chipped

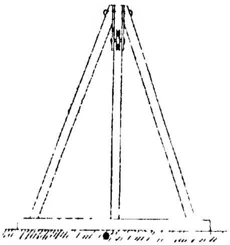


Fig. 67.—Boring Headgear or Derrick.

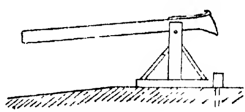


Fig. 68.—Lever or Brakestaff.

away by the chisel being alternately raised and allowed to drop. Boring in this way, by a series of blows of the cutting tool delivered on to the rock, or, as in the

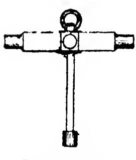


Fig. 69.—Bracehead or Tiller. A single bracehead has two arms; a double bracehead four arms.

Fig. 70.—Bore-rod.

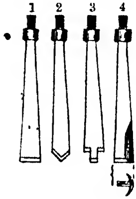


Fig. 71.—Chisels.

1, Flat chisel; 2, diamond-pointed or V-chisel; 3, Continental V-chisel; 4, T-chisel.

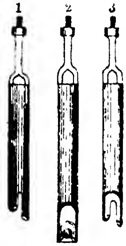


Fig. 72.—1, Auger; 2, Ball-valve Sludger; 3, Wimble.

case of the hammer and hand drill (fig. 135), on to the end of the drill, is known as *percussive boring.*

109. **The Ordinary System.**—The general process in

ordinary boring is as follows: A *guide tube* is necessary at the surface to ensure that the chisel will descend quite vertically. This guide tube is sunk into the ground; the *rods* work up and down through it. As will be seen from the figures there is a screw at one end of the chisel and at both ends of each rod. By means of the screw ends the chisel is connected to the bottom rod, the rods one to another, and the top rod to the short length of rod which forms part of the *bracehead*. Thus, when the hole has been bored down a certain distance, there will be a long string of boring rods in it, extending from bracehead at surface to chisel at bottom.

Fig 73.—Hook to Lift Rods

During the earlier part of the boring the men grasp the bracehead and raise it, and the rods and chisel connected to it; then they let the whole mass drop, the chisel thus cutting into the rock. These operations are continued steadily, the men moving slowly round in a circle. The circular movement is to ensure that the hole will be as round as possible, and that every blow of the chisel will fall on a fresh place; in making it, the borers have to be careful to follow the direction that will not result in the unscrewing of the rods.

After a time the bottom of the hole becomes choked up with the broken rock material, or "borings" as it is called, and requires to be cleaned out. To do this the rods and chisel must be withdrawn from the hole, which is accomplished by the aid of a windlass and rope. The windlass is fixed to two legs of the headgear (fig. 67), or placed a short distance away from the latter. The rope passes from the windlass over the pulley shown in the headgear; a hook (fig. 73) is attached to the end of it.

In withdrawing the rods the bracehead is unscrewed and the rope connected to the former by passing the

ook under a joint. The men then work the windlass, nd the rods rise slowly out of the hole. When they have een drawn up as far as the height of the pulley permits, ie windlass is stopped. The rods are now hanging ispended from the rope, and if the borers were to unrew the part at the surface the rods left in the hole, nd chisel, would drop down to the bottom. To prevent iis the fork illustrated in fig. 74 is placed over the hole id the rods lowered a little until a joint of the latter is esting on the fork. Then the length of rods above this int is unscrewed by the aid of the key (fig. 75), and emoved The rope is again hooked to the rods and

Fig 74.—Fork or Retaining Key

Fig. 75 —Screw-key

ie latter raised, the various operations of attaching ie hook to the rods, working the windlass, &c., being peated as often as necessary until all the rods and the iisel have been withdrawn. When the hole has been eaned the chisel and rods are replaced, the procedure eing exactly the reverse of that used in their withrawal.

In cleaning the hole the *sludger* (fig. 72) is used. It hollow, and has a valve at the bottom. It is lowered y means of the rope, the sludge passing into it as it escends. As it is drawn upwards the valve closes, thus reventing the sludge from falling out.

As the hole deepens new lengths of rods are added at ie top, and when the weight becomes too great for the en at the bracehead to raise, the *lever* or *brakestaff* ig. 68) is brought into use. This is provided at one id with a hook, and from this the bracehead, with rods id chisel attached, is suspended by means of a short

chain, or an appliance called a *stirrup*. The men alternately depress and let go the other end, in this way raising and letting fall the rods in the hole. The master borer, grasping the bracehead, moves slowly round in the manner already described, thus giving the chisel a partial turn after each blow.

When the chisel passes into a new bed of rock the man at the bracehead feels a difference, and in this way the thickness of each stratum is ascertained. The master borer carefully examines the contents of the sludger when it is drawn up, also the chisels, to find out the nature of the rock, and all particulars are carefully entered in a book.

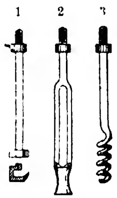


Fig 76.—Tools for Extracting Broken Rods

1, Crow's-foot, 2, bell, 3, spiral worm.

Sometimes the rods break and special tools (fig. 76) are then necessary to recover them. Also in soft ground the hole sometimes requires to be lined with iron tubes; if possible, these tubes must be recovered when the boring is finished. For very deep holes special appliances are required to overcome the difficulties due to the great weight of the rods in the hole, and instead of men a steam engine is generally employed to operate the lever, &c.

The ordinary system of boring, modified to suit the conditions, is also used underground to prove strata, as in the case of a fault, and for other purposes, as to tap water, &c.

110. **The Diamond System.**—This is a type of *rotary* boring. In percussive boring, we have seen, the rock at the end or bottom of the hole is chipped or broken away under the force of a series of blows delivered on to it or transmitted by the cutting tool. But it is different in rotary boring. In the latter method, as

implied by the name, the boring tool is made to *rotate* or turn round and round—always in one direction—so that the cutting part presses steadily against the ground at the end of the hole. In one form of rotary boring—the form used in boring holes for blasting—the drill (fig. 137) is of a twisted shape, and grinds the rock in front of it into dust, thus forming only the hole itself. But in the diamond system a ring or annular space is bored, leaving a solid core in the centre (figs. 77–8). This core is extracted at intervals, and affords excellent samples of the strata passed through.

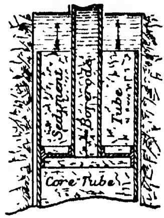


Fig 77 – Showing Core and Annular Space cut by Diamond Drill

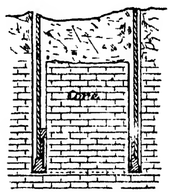


Fig 78 — Diamond Method of Boring

The cutting part in the diamond system is called the *crown* (fig. 78), and is set with real diamonds, the diamond being the hardest substance known. The ones used are black in colour, valueless as jewels, but yet very costly.

The crown is screwed to the *core tube*, and above this are the *rods*. The whole is made to revolve rapidly by an engine at the surface. The rods are hollow, and

a stream of water is forced down them by a pump on the surface. This water rises up outside the crown, core tube, and rods, and carries with it the rock matter produced by the crown in forming the ring or annular space. As the water nears the surface its force weakens, and any heavy pieces of material which would tend to drop back are caught in the sediment tube.

The core as it is formed passes into the core tube and is prevented from falling out when being drawn up to the surface by means of a special ring placed at the foot of the tube.

The diamond system of boring is much quicker than the ordinary method, and gives a perfect knowledge of the ground passed through. It has, however, certain disadvantages, and therefore the ordinary or other system is often preferred. On account of the cost of the diamonds substitutes are sometimes used. Hand-boring diamond machines are also sometimes employed both above and below ground.

CHAPTER XIX

GETTING DOWN TO THE COAL

Preliminary Considerations—Sinking and securing a Circular Shaft—Special Methods of Sinking.

111. **Preliminary Considerations.**—Satisfactory evidence having been obtained on the existence of coal in quantities that will pay for the working, and on all the other points required, the next step in the starting of a colliery is to get down to the seam or seams. Before this can be entered on, however, certain very important questions require to be considered. These are as to the

number of openings or entrances to be made to the seam or seams, the position of such openings or entrances, and their size and form.

112. **Number of Openings to the Seam.**—In regard to the number of openings or entrances to the seam, at least two are usually necessary, though under certain exceptional circumstances there may be only one. This is made compulsory by the *Coal Mines Regulation Act*, an Act of Parliament passed in 1887, which states that, except under certain conditions, "there must be two shafts or outlets to every seam". But while two, then, is the minimum number of entrances or outlets to an ordinary seam, more than two may be required for the efficient working of the mine; and this, therefore, forms one of the questions that must be settled before the actual operations of getting down to the coal are begun.

113. **Position of Openings or Shafts.**—The next question to be considered is that of the position of the entrances to the seam. In deciding this many things have to be taken into account, as, for example, the inclination of the seam (the information obtained in the boring being here utilized), its depth from the surface, the nature of the ground at or near the surface, the proximity to a railway, &c. The problem is to have the entrances or outlets in a place that will permit of the coal being produced and sent into the market at the lowest possible cost (§ 106), and the solving of this problem is often attended with great difficulty.

If the coal outcrops, the task may be much simplified. Two or more "roads" or openings called *day drifts*, or *daylight mines*, &c., may be started at the surface and driven down in the seam itself—sometimes they are driven in the stone, and sometimes partly in both according to circumstances. Lines of rails are laid in these and the coal brought to the surface in little

wagons called *tubs* or *hutches* (fig. 168). But usually in Britain the seams lie at such a depth below the surface that *shafts* (fig. 38) are required. These are openings or passages cut straight down through the strata. They are generally very costly, and in fixing their position the greatest care and foresight are necessary.

Shafts may, of course, be sunk even where the coal outcrops, and in some instances there are both shafts and drifts. In all cases the two shafts or outlets "must not at any point be nearer to one another than fifteen yards", and must be connected by a passage "not less than four feet high and four feet wide". This also is rendered compulsory by the *Coal Mines Regulation Act.*

114. **Size and Form of Shafts.**—In fixing the size and form of shafts there is not so much difficulty as in determining their position. The size will be decided mainly by the output, or number of tons of coal per day raised; while the form or shape will depend a great deal on the custom of the country or locality in which the shafts are to be sunk. In England and on the Continent *circular* shafts (fig. 84) are preferred, while in Scotland rectangular forms (fig. 90) are the rule. The latter form is also used much in America. But a circular shaft is stronger than a rectangular one, and therefore, where the ground is of such a nature as to require great strength of shaft, or some special method of sinking, the circular form is usually adopted, even in Scotland. Shafts may also be *square, elliptical* or *polygonal* in shape.

115. **Sinking and Securing a Circular Shaft.**—Now in sinking any kind of shaft the work is not confined to excavating and removing the material. The shaft sides must be supported or they will collapse and fall in on the workmen. Then water usually finds its way into

the pit bottom and must be dealt with or it will rise up in the shaft and put a stop to the whole sinking operations.

116 **Ground through which Coal Pits have to be Sunk.**—The first part of the sinking is not always the easiest, as might be thought. The whole ground to be passed through, as was seen in our geology lessons, consists of the more or less soft beds at or near the surface and the hard rock beds lying farther down. The top of the first hard rock bed is called the *stonehead*, and getting down to the stonehead is the first operation in sinking.

117. **Getting Down to the Stonehead.**—Now, getting down to the stonehead is often very difficult. Sometimes part of the ground consists of quicksand or heavily watered strata, and then great trouble is sure to be experienced. Usually in such cases some special method of sinking,[1] to suit the nature of the ground, has to be adopted. We may suppose, however, that the strata are such as are ordinarily met with, and that no special difficulties are encountered in the sinking.

The first step will be to provide all the necessary tools and appliances, that there may be no delay when once the actual sinking operations have been commenced. The tools will include picks, shovels, wedges, blasting gear, saws, axes, hammers, &c., while the appliances will comprise at least *kibbles* (also called *kettles*, *hoppits*, and *bowks*), a *headgear* with landing stage and pulley (fig. 79) and a stationary engine with drum and rope. Temporary erections, such as blacksmiths' and joiners' shops will also be required.

When the preliminary arrangements have been completed, the sinking is commenced. The position of the shaft is carefully marked off on the surface and then

[1] See end of chapter.

the ground dug out to a depth of about 6 ft. The shaft sides will now need to be supported to prevent them from falling in. For this purpose timber is first used. Afterwards, when the stonehead is reached, a circular wall is built right up to the surface (figs. 84–5) and the timber taken out.

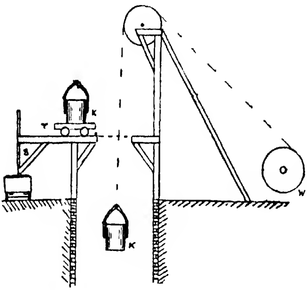
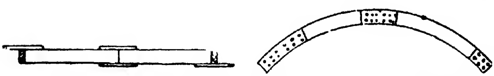


Fig 79.—Raising and Tipping the Material at a Sinking Pit

W, Winding drum; *k, k*, kibbles or kettles, T, bogie or trolley, S, shoot

The timber fittings (figs. 80–2) consist of *curbs or cribs, backing deals or laggings, punch props, and stringing deals*. Instead of the curbs, *iron rings* are sometimes used, and instead of the stringing deals *strips of flat iron*.

As will be seen from fig. 82, the backing deals stand against the strata, thus supporting the beds and preventing any rock material from falling into the shaft.



Figs 80, 81 —Front View and Plan of Two Segments of a Curb, showing cleats

They are simply boards about 9 ft. long and 1 in. thick. The curbs are circular frames constructed to suit the circumference of the shaft. They are made of hard wood and hold the backing deals in position. Each, it will be seen, consists of a number of parts or *segments*

joined together by *cleats* (figs. 80, 81). The punch props are placed between the curbs (fig. 82), and the stringing deals nailed to the front of the latter and to beams placed across the mouth of the shaft at the surface, the props and deals thus supporting and keeping the curbs in their places. The timbering is carried up about 3 ft. above the surface level of the ground, to enable the excavated material to be emptied or "tipped" easily.

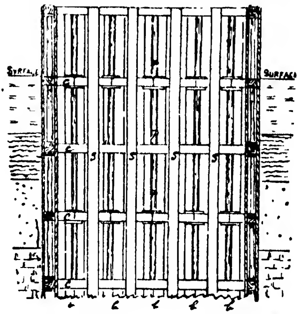


Fig 82 —Temporary Lining for Circular Shaft

c, Curbs; *b*, backing deals, *p*, punch props; *s*, stringing deals.

Sinking can now be resumed for another few feet and a new section of timbering put in, this new section being joined to the part above. Then more material is excavated and additional timbering put in, the processes of sinking and securing the shaft sides being continued alternately until the stonehead is reached.

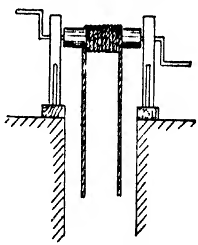


Fig. 83.—Windlass

118. **Raising the Material.**—At first the clay, &c., is thrown to the surface, but about 12 ft. down the depth becomes too great for this and the kibble is used. Sometimes the latter is raised and lowered by men working a windlass (fig. 83), but this is only suitable for shallow

depths, and a steam engine is generally employed (fig. 79). In loading the kibble care must be taken to see that no stones, &c., can fall out, and that no material is adhering to the outside, as anything dropping down the shaft might fall upon and injure the sinkers. For the same reason the landing stage or scaffold at the mouth of the shaft (fig. 79) is made so as to leave an opening only large enough for the kibble to pass through. Very often in emptying the kibble it is merely swung clear of the shaft, but sometimes a *bogie* or *trolley* is used, as illustrated in fig. 79. Sometimes the opening at the top of the shaft is fitted with folding doors, which are opened to allow the kibble to pass up through, but at other times are kept closed.

When the kibble is travelling in the shaft it hangs from a spring hook at the end of the winding rope, and is often not guided in any way. It therefore tends to swing about or oscillate, and to prevent this *guide ropes* and an appliance called a *rider* are sometimes employed.

The men engaged in the excavation of the material are termed *sinkers*, and in putting down deep shafts a considerable number of sinkers may be employed, as the work is usually continued throughout the twenty-four hours. As one set of sinkers "leaves off" another set begins, the portion of the twenty-four hours during which each set works being called a *shift*. During each shift the operations are in charge of a "leader", "foreman", or "chargeman". To secure the utmost safety special rules for the conduct and guidance of all persons engaged have been instituted, and these require to be very carefully observed.

119. **Walling the Shaft from the Stonehead to the Surface.**—As already stated, when the stonehead is reached a circular wall of brick is built up and the

timber taken out. This wall forms the *permanent lining* of the shaft, the timber being thus *temporary lining*.

Before commencing to build the wall the shaft bottom is levelled very accurately. Then on the levelled surface a walling curb is laid down (fig. 84). This is in parts or segments like the curbs in the temporary lining. It may be of wood but is often constructed of cast iron, the segments in the latter case being bolted together.

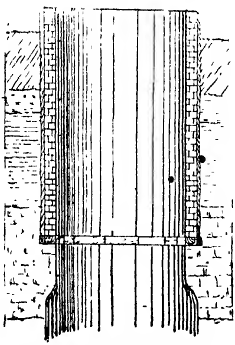


Fig. 84.—Section of Circular Shaft, showing walling

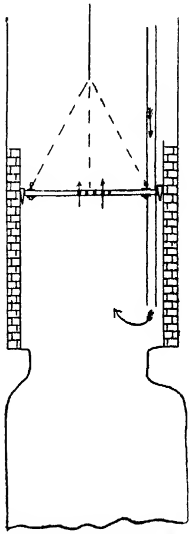


Fig 85 – Walling Stage or Cradle

The wall is erected on the top of the walling curb. As it is built up, the timber or temporary lining is removed and the space between the permanent lining and the strata packed with some light material such as fine ashes.

In building the wall regular bricklayers are em-

ployed. They stand on a circular platform, called a *walling stage* or *cradle.* This is suspended in the shaft by a rope (fig. 85) to which it is connected by four or six chains and must be strong enough to carry the men and a quantity of building material. By means of the rope it can be moved up or down the shaft as required.

120. **Special Methods of Sinking.**—As has been mentioned (§ 117), getting down to the stonehead is sometimes very difficult, owing to the nature of the ground. If another site for the shaft in good ground and equally suitable is available it will be adopted, but such alternative may not be possible and the shafts have to be put down through the bad ground. Some special method of sinking, suited to the conditions, has then, as we have seen, to be adopted.

121. **Pile Sinking.**—An old method, sometimes yet adopted, of sinking through loose and running ground, is that known as *piling.* A pile is a plank having the lower end tapered to a cutting edge and the upper end protected by an iron hoop. A sufficient number to form a large circle or ring—much larger than the required finished size of shaft—are driven down edge to edge. As the material is removed from within the circle, curbs are put in to keep the planks in their places. Then a second circle of piles is driven down inside the first and supported by curbs as the sand, &c., is removed. If necessary a third circle is driven down inside the second, and a fourth inside the third, and so on until the solid rock is reached. A walling curb is then laid down, and the permanent walling built up in front of the piles.

122. **Cylinders or Drums.**—A more modern method is to use *cylinders* (also called *drums*) of brick, brick and wood, or iron. The cylinders are provided with a cutting edge at bottom. The first two sink by their own

weight as the rock material is removed from the interior, but the iron cylinder has to be loaded, or pressure applied in some way, to force it down. The cylinders are added to at the top as they continue to sink. Means have to be taken to ensure that they descend quite vertically, iron cylinders being suspended by chains and screws from beams placed across the mouth of the shaft. Sometimes sinking by cylinders is termed *caisson sinking*.

123. **Sinking by Compressed Air.**—Another method of caisson sinking is that in which compressed air is used. This is sometimes called the *Triger system*, from the name of the person who first employed it. In this method the cylinder is divided into air-tight compartments and the compressed air forced into the bottom one. The pressure of the air is sufficient to keep the water in the sand from entering the compartment, thus allowing the men to work. The high pressure of the air, however, necessary for this purpose, is very injurious to the workmen, and therefore Triger's method can only be used where the depth is limited—not much beyond 100 ft.

124. **Freezing Systems.**—In another method of sinking called *Poetsch's freezing system*, also from the name of the inventor, the running sand is frozen hard by means of a congealing liquid made to circulate through tubes bored into the ground. When the ground has been frozen hard it is dug out by means of pick, shovel, and wedge, and permanent walling afterwards built up. A modification of this method is known as *Gobert's system*.

125. **Boring the Shaft.**—In the *Kind-Chaudron system*, used in hard strata giving off great quantities of water (so large that it would be quite impossible to prevent the shaft from being filled up), the shaft is *bored* out. The tools employed are called *trepans*. First a small

trepan is used to bore a hole, or small pit, a certain diameter and depth, then it is replaced by a larger one which bores out the shaft to its full size. This is continued until the water-bearing strata have been pierced, the trepans being used alternately and the boring made by the smaller one, always kept a certain distance in advance of that made by the larger. When the watery strata have been bored through, an iron cylinder with a water-tight joint at the bottom, called the "moss-box" (because moss is used in making it water-tight), is lowered into the shaft while the latter is still full of water. After the cylinder has been got into its position the space at the back is filled up with cement concrete. When the concrete has set, the water is pumped out of the cylinder, the water-tight joint preventing any more from entering. All this time no one has entered the shaft, but the men now descend and begin sinking in the ordinary way.

The trepans are constructed of ironwork and are very heavy, the smaller one used at the sinking of the Dover Colliery shafts weighing about 10 tons and the larger one about 25 tons. Each is provided with large steel teeth or chisels, the larger one having in addition a "guide" which fits into the hole bored by the smaller trepan. They are connected to a steam engine by rods. The engine raises the trepan a short distance and then allows it to drop, thus cutting away the rock.

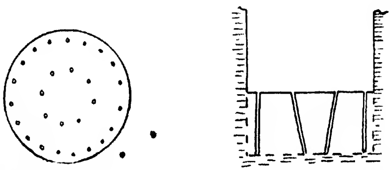
The term "Kind-Chaudron" is from the names of the inventors, and, as in the case of Poetsch's freezing system, there are modifications of this method

CHAPTER XX

GETTING DOWN TO THE COAL—(*Continued*)

Sinking a Circular Shaft from the Stonehead—Keeping the Shaft Vertical, &c.—Sinking a Rectangular Shaft.

126. **Sinking a Circular Shaft from the Stonehead.**—The ground will now be too hard to be dug out with pick and shovel, and must therefore be blasted. We shall learn fully in chap. xxx as to this subject, but meantime we may note that, in breaking up the ground by blasting, holes must be bored to hold the explosive substance. The holes are arranged as shown in figs. 86, 87,



Figs 86, 87 —Plan and Section, showing Arrangement of Shot Holes at Bottom of Sinking Pit

the inner ones being called *sumping-holes* and the outer ones *side-holes* (or *canch-holes*). The sumping-holes are fired first. They are put down with a slope or inclination towards the centre of the shaft (fig. 87), the number in the circle (fig. 86), and their position and depth, depending on the diameter of the shaft and the nature of the rock. They are heavily charged with explosive, and when fired form a space in the shaft bottom called a *sump* or *sumphole*. This sumphole is of use in collecting the water that comes into the shaft, enabling it to be baled into the kettle more easily, and tending to keep

the rest of the shaft bottom dry. It also makes the work of the side shots less, as the rock to be displaced, being free on the side next the sumphole, is more easily dislodged than if it were completely solid, as in the case of the sumping shots. This is expressed in mining phraseology by saying that the side shots are "in the solid on one side" or have one "fast side". Often also the term "cut" is used, the open space formed by the first shots being called the "cut", and the second or succeeding shots being said to have been given "cut". As has been stated, when a shot has cut, or is in the solid only on one side, the rock is more easily dislodged than when it is completely in the solid. A smaller amount of explosive substance, then, will be required for a shot that has cut than for the same shot without cut. The side-holes are charged and fired in the same way as the sumping-holes, the work of drilling the holes being commenced as soon as the debris produced by the sumping shots can be cleared away from the ground next the shaft sides. Sometimes all the holes are bored before setting off the sump shots, and in that case the side-holes are stopped to prevent any rock material from entering.

In rectangular shafts the ground is broken up in like manner, only the sumphole is formed near one end (called the *dip* end), and the other holes arranged across the shaft, parallel to the shorter side, one row being fired after another. In all shafts great skill is required in deciding the position of the shot holes, their number, depth, and inclination.

In firing (also called "lighting" or "setting off") the shots, the utmost care is necessary. All the tools are removed to the surface; the sinkers also ascend, leaving only the chargeman and one other man in the shaft bottom. These see that the kibble is ready, then quickly

light the fuses, and, mounting the kibble, are drawn up to the surface. The fuses burn very slowly. One end of each is connected to the explosive inside the hole (in the way to be explained in chap. xxx); the other end (the end that is lighted) projects far enough to permit of the chargeman and his assistant reaching the surface in safety. As the shots go off they are counted. If any fail to explode, then a considerable time (see *Special Rules*) must be allowed to pass before any person enters the shaft. In most sinking pits the shots are now fired by electricity. This is safer, as all the men are on the surface before the electric cables are connected to the exploder (figs 141–2). But in electric firing the shots explode simultaneously and cannot be counted.

In boring the shot holes hand drills (fig. 135) and hammers are sometimes used, but very often machines are employed, these being worked by men, by compressed air, or by electricity.

127. **Use of Temporary Lining.**—Now, in sinking a circular shaft from the stonehead downwards the sides of the shaft may or may not be lined temporarily. It depends on the hardness of the strata. If temporary lining is not used, then great care has to be taken to see that the sides are quite free from loose stones, lest these should afterwards become detached and drop down on to the sinkers. Regular inspection of the sides is also necessary.

128. **Method of Sinking and Putting In the Permanent Lining.**—Whether the sides are lined temporarily or not, the walling is put in in sections or lengths, part after part of the shaft being secured as the sinking proceeds, and each new section of walling joined to the part above. A support is left for the walling curb and section of walling already put in by carrying down the sinking for a few feet in a line with the inside of the curb (fig. 84).

When a sufficient support has been left, the shaft is opened out to its full diameter and continued at this down to the point where it is considered advisable to begin a section of walling. This section is started and built up in exactly the same way as was the one from the stonehead to the surface. When the walling reaches the curb support, the latter is cut away and the walling brought up to the under side of the curb, the ledge not being all removed at once, but part after part, and the walling brought up until the whole circumference of the shaft has been treated. This is called *underpinning*. Other sections of walling are put in in a similar way. Sometimes the cradle is so constructed as to permit of the sinking going on below while the section above is being secured with walling, thus enabling the shafts to be sunk in a shorter period than is possible where the sinking operations have to be stopped while the bricklayers are at work.

129. **Keeping the Shaft Vertical.**—Great care must be taken to keep the shafts quite vertical. A *plumb line* is suspended in the exact centre of the shaft. By measuring from the plumb line with a wooden rod, called a *radius rod* or *centre staff*, the master sinker can tell whether the walling curb is in its proper position, and also at any time whether sufficient of the rock has been removed to let in the walling curb and walling.

The curbs must be exactly under each other, and in putting one in, plumb lines are hung from the curb above. These extend down to the front of the curb being put in, which can thus be set in a line with the one above, but the position of every third curb is checked from the main plumb line in the centre of the shaft.

The main plumb line is passed through a hole bored in a plank laid across the mouth of the shaft. It is

kept steady by immersing the "plumb bob", or weight attached to it, in a bucket of water. Sometimes, instead of the plank, another arrangement is used. When not in use the plumb line is kept coiled on a little drum or reel.

130. **Ventilating and Lighting the Shaft.**—When the shaft has been sunk down a certain distance, means require to be taken to ensure a constant supply of fresh air for the sinkers, and for driving out quickly the smoke produced by the blasting and the gases which are sometimes given off from the strata. Different methods are adopted for this purpose. Sometimes the shaft is divided into compartments by a partition termed a *brattice*, and a current of air made to travel down one compartment and up the other. A common method is to fix pipes of sheet iron or wood down the side of the shaft and connect these to a machine on the surface called a *fan*. The fan forces the fresh air down the pipes—air, smoke, &c., rising up the shaft to the surface. An air pipe is shown in fig. 85. Where compressed air is used for working the drills at the bottom of the shaft the air can be employed for the purposes of ventilation.

131. For **lighting the shaft** electric lamps are sometimes adopted, especially if the shaft is large and deep. During blasting the lamps are hoisted up out of danger and afterwards lowered down again. Very often the sinkers just use little oil lamps which are hooked to the front of their hats or caps. To prevent the flame from being extinguished by drops of water it is protected by a tin shield.

If the gas known as *firedamp* is likely to be met with in the sinking, then only safety lamps (chap. xxxvi) must be employed.

132. **Dealing with Water.**—As already mentioned, § 115, water usually enters the shaft from the adjacent rocks.

If the quantity is not very great it may be baled into the kibble and taken up to the surface with the debris, or the kibble may be filled with water alone when there is no rock material ready to be wound up. If, however, the amount of water is too large for this, *water barrels* or *pumps* are used. Where water barrels are employed they are usually arranged to dip into a collecting tank fixed a certain distance above the shaft bottom. The water in the shaft bottom is raised into the tank by a small steam pump. The tank can be lowered as the sinking proceeds.

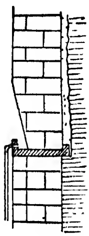


Fig 88.—Water Ring or Garland, and Pipe to carry Water down Shaft

133. To prevent the water from running down the front of the brickwork *water rings* or *garlands* are employed. These are built into the walling at intervals. They are constructed in different ways. A common form is shown in fig. 88. It is of cast iron, similar to a walling curb, but with a groove in front running round the whole circumference of the shaft. For a short distance above the groove the brickwork is cut or "shorn" back to let the water enter the ring easily. Very often a walling curb combines both a walling curb and water ring.

The water that collects in the ring is carried down in a tube or pipe to the next water ring or to the bottom of the shaft or tank fixed above it. Sometimes these pipes are led into special excavations made in the strata adjoining the shaft. Such excavations, termed *lodgments*, are for the purpose of affording standage for water.

134. Where the quantity of water given off by the strata is very great it is desirable, if possible, to dam it back in the rocks and thus prevent it from entering the shaft. But this is only practicable where the water-

bearing beds are underlain by impervious beds through which the water cannot afterwards find its way into the pit Sometimes a water-tight lining of brick and cement, called *coffering*, is employed, but more usually *cast-iron tubbing* requires to be adopted. This consists of cast-iron plates built up on a *wedging curb* (fig. 89). The plates are curved to suit the circle of the shaft. They are joined end to end right round the circumference, and one circle stands on the top of another. They are made perfectly tight by means of wood wedges. Each plate has a hole in the centre to allow the water to run off while the tubbing is being built up in the shaft. Afterwards these holes are plugged up.

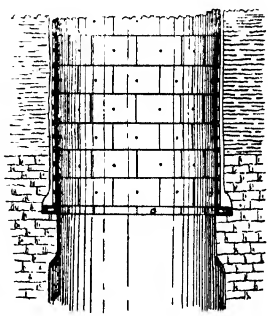


Fig 89 —Cast-iron Tubbing
c, Wedging Curb

135. Sinking and Timbering a Rectangular Shaft.—The process of sinking a rectangular shaft is similar to that of a circular one so far as digging the rock material and removing it with the kettle is concerned, and also as regards the ventilation, &c. (see method of breaking up the ground, § 126). But the method of securing the sides is quite different. Rectangular shafts are usually lined permanently with timber, not with bricks as in the case of circular shafts. Nor is temporary lining used, the timber first put in being allowed to remain until it is broken or has become so decayed as to require to be renewed.

As will be seen from fig. 90, the fittings consist of

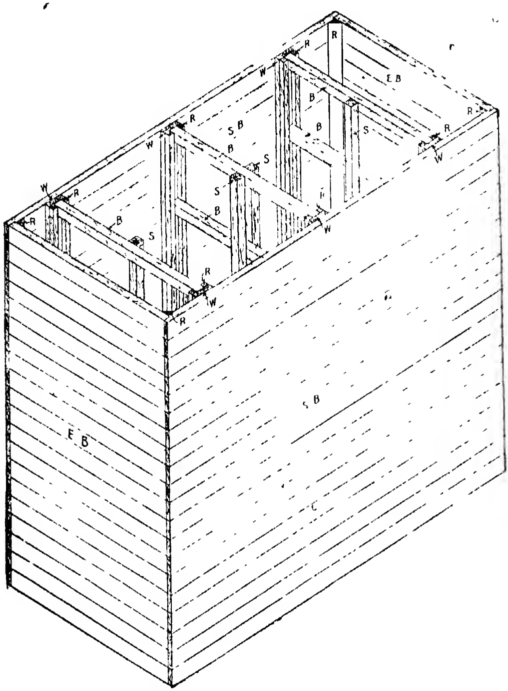


Fig 90 —Timbering of Rectangular Shaft

SB, Side barring, EB, end barring; R, racking; B, buntons, W, wall-plates; S, slides or conductors

side barring, end barring, buntons, wall plates, and *corner rackings.* Short pieces of wood termed "filling-in pieces" are now also sometimes used. The side and end bars may be described as planks. They form a

frame which is strengthened at the corners by the corner rackings, or, sometimes, angle irons, the corner rackings being long pieces of wood, either square or triangular in shape, nailed to the barring. Usually the side and end bars are notched into each other, as shown in fig. 90. The wall-plates, also planks, are spiked to the side barring on each side of the shaft. They are at right angles to the side bars, and thus form vertical lines of planks right down the shaft. The buntons, square or rectangular beams, are placed between opposite pairs of wall-plates. They thus stretch from one side of the shaft to the other, giving support to the side bars. It will be seen that the buntons also divide the shaft into compartments, and to them are fixed the *slides* or cage guides. The vertical distance between the buntons depends on the nature of the strata, but is usually from about 3 to 6 ft. Between each pair at the ends, or next the wall-plates, the filling-in pieces (or "punch props") when used are placed (not shown in figure). These assist in keeping the buntons in their places, and also add to their strength. Sometimes, instead of filling-in pieces wood brackets are nailed to the wall-plates under the ends of the buntons.

Rectangular shafts, like circular ones, are secured part after part as the sinking proceeds. The barring is built upwards, edge to edge, until it reaches the section above. It is wedged tight at the corners, and also opposite the buntons, wood wedges being driven in between the bars and the strata. The rest of the space behind the barring is packed with some light material through which water can drain easily.

CHAPTER XXI

WORKING THE COAL

Water Standage—Preparatory Operations—Keeping a Road in its Course—Keeping the Gradient.

136. **Water Standage.**—In the two preceding chapters we saw the steps necessary to get down to the coal. The sinking, however, does not terminate at the seam (or lowest seam intended to be worked). It is continued for a short distance in the stone below the coal, the excavation thus formed—from the floor or bottom level of the seam down to the extremity of the shaft—being called the *sump* (fig. 38). The sump is, then, really a continuation of the shaft. It serves as a "standage" for the water which, as has been seen, may drain down the shaft, or which may be brought from some part of the mine (chap. xl), the sump thus keeping the shaft sidings or landings at the pit bottom dry. But where the quantity of water is large the storage capacity of the sump will not be sufficient, and a lodgment (§ 133) will require to be formed in connection with it, either in the seam itself or the stone under the seam.

137. **Preparatory Operations.**—The sinking of the shaft being now completed, the *main roads* or *levels* will be commenced, the *shaft pillar* formed, and the necessary connection (§ 113) between the two shafts or outlets made, these operations being preparatory to the general excavation of the seam.

138. **The Main Roads.**—The main roads, as implied by the name, are the principal thoroughfares of the mine. They lead from the shafts to the innermost parts, forming, as it were, "highways" between the shaft and the mine workings or districts where the coal is being exca-

vated (fig. 113). They must therefore be wide and high, and, in order that falls of rock material from roof and sides may, so far as possible, be avoided, require to be secured very thoroughly, in the way afterwards to be shown.

139. **The Shaft Pillar.**—The shaft pillar (fig. 113) is a large mass of coal left unworked all round the shaft or shafts. It supports the strata above, hence the term "pillar". If there were no shaft pillar, or, in other words, if the coal round the shaft was all taken out, then the rocks in the vicinity of the shaft would subside, and, as a result of this, the shaft walling and erections on the surface might collapse To guard against this, then, this part of the seam is left untouched, except for driving the necessary roads through it.

In Scotland the term "bottom stoop" is generally used, "stoop" here meaning "pillar", and therefore "bottom stoop" the "stoop" or "pillar" of coal at the bottom of the shaft.

The size of the shaft pillar is different for different seams. It depends on many things, such as the depth from the surface, the thickness and inclination of the seam, the nature of the strata above the seam, &c. It is sometimes very large.

140. **Direction of the Main Roads.**—The direction of the main roads is very important. They are generally started from opposite points in the shaft, and continued right through the seam (fig. 113), but their exact course or route must first be decided. This, like the size of the shaft pillar, depends on many things—the position of the shafts, the inclination of the seam, the system of haulage (chap. xxxvii), the method of working the coal (chaps. xxiii–xxv), the position of known faults, &c., and whether water is given off in the mine, all having to be taken into account. If the seam is flat all the

roads in the mine will be level, but if, as is usually the case (§ 53), it is more or less inclined the main roads may or may not be level, according to what is thought best in view of all the circumstances mentioned. Thus, if the system of haulage is by horses, it is considered advisable to have the main roads rising slightly from the shaft, in order that the horses may not have to exert a greater force in pulling the full hutches to the shaft bottom than in hauling the empty ones into the workings. The direction of the main roads, then, would need to be such as to permit of this gradual slope upwards from the shaft. Again, if water is given off in the seam it is desirable that it should flow to the sump, and that is only possible if, in making the roads, a slightly uphill course has been followed. Such roads are called "levels" by miners, though, since they dip slightly towards the shaft, it is obvious that they are not quite level. Then, again, if the system of haulage is mechanical, such as, say, a steam engine working a rope (fig. 174), it is a great advantage if the engine planes (or main roads) can be constructed free from curves, and accordingly the straightness of the roads becomes a subject of consideration as well as the gradient.

141. **Number of Main Roads.**—Usually for the sake of ventilation two parallel roads a short distance apart are driven, the air passing from the downcast shaft along one of the roads and returning to the upcast shaft by the other (fig. 150). But sometimes, where water is given off, a third or special level, termed a *water level*, is formed.

142. **Keeping the Road in its Course.**—The extreme end of the road, or the part where the miner is at work cutting away the material, is called the *face* (sometimes the "end"), and when a road has to be driven in a particular direction means must be taken to keep the face

advancing in the proper course. For this purpose plumb lines (P, fig. 91) are used. By the aid of a compass or theodolite (figs. 199–200), marks are made on the roof coinciding with the direction the road has to go. The marks are usually three in number, and are a short distance apart. Holes are then made at the marks, and the plumb lines suspended from wood plugs inserted into the holes. Thus the plumb lines hang down from the roof, one exactly in front of another (fig. 91), the three giving a straight line corresponding to that formed

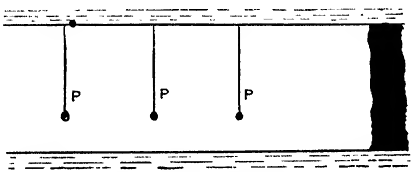


Fig. 91 – Plumb or Sight Lines

by the points or marks on the roof, and therefore indicating the direction in which the excavation must proceed. Anyone, then, placing his eye to the plumb line farthest from the face can tell whether a light held at the face is in a line with the plumb lines, and therefore whether the road is going in its proper direction or not. Sometimes the plumb lines are termed "sight lines" or "sights" (or "views"), and in taking a "sight" or observation (or "view") a light must be held against the lines nearest the face as well as at the face.

Often the plumb lines are hung in the centre of the road, and the light at the face must then be at the centre of the excavation, when in line with the plumbs. But if, as is considered better, the plumb lines are suspended a certain distance from one side of the road,

then, if the road is following its proper course, a person "taking the views" ought to see the light at the face at the same distance from the side of the road as are the plumb lines.

By taking sights frequently it is possible to keep the road going quite straight in the required direction. Sometimes only two plumb lines are used, but three are better, as, if the position of any one line becomes altered through movement of the strata, the change is more easily detected with three than with two lines. Movement of the strata may also cause the timber or other supports to the roof to shift, and for that reason the plumb lines, where possible to avoid it, ought not to be hung from these.

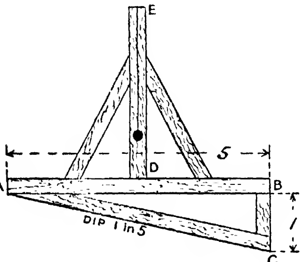


Fig 92.—T-bob or Plumb-bob

143. **Keeping the Gradient.**—To keep a road at a given inclination an appliance such as illustrated by fig. 92 is sometimes used. This is called a *plumb-bob*, or T-*bob*, from its resemblance to an inverted T. It is constructed strongly of wood, AB being a horizontal piece, DE a vertical piece carrying a plumb and being stayed by two side pieces, AC a sole piece set at the angle the road has to rise or dip.

In checking the gradient, AC rests on the floor, and if the inclination is correct AB will then be horizontal and the plummet hang in the centre of the vertical piece DE. If, however, the road is not at its proper

gradient, then AB will not be horizontal, and the plummet will hang outside the centre of DE.

Sometimes a hole is made in the vertical piece for the reception of the plummet, and in addition to the latter a spirit level is placed on the horizontal piece AB. When AB is quite level the air bubble of the spirit level will be at its central point.

The figure represents a T-bob for a gradient of 1 in 5, the horizontal piece AB being 5 ft. long and the short vertical piece 1 ft. (§ 53). If the road were to be level, then the pieces AC and BC would not be required, and T-bobs are often constructed without these. In that case if the T-bob were used in an inclined road a small piece of wood of a certain thickness would be screwed to the under side of AB at one end. The thickness of this small piece of wood would depend on the inclination of the road and the length of AB, and the T-bob would require to be placed so that the end of AB carrying the small piece of wood would be downhill. This is in order that AB may be horizontal.

As an example of this kind of T-bob: If AB were 3 ft. long, and the road were to rise or fall $\frac{1}{2}$ in. per yard (or 1 in 72), the piece of wood would be $\frac{1}{2}$ in. thick; if AB were 6 ft. long, then for the same gradient the thickness of the small piece of wood would be 1 in. Again, if the thickness of the small piece of wood were $\frac{1}{4}$ in. and AB 3 ft. long, the gradient would be $\frac{1}{4}$ in. per yard, or 1 in 144; for the same inclination, if AB were 6 ft. long, the small piece of wood would require to be $\frac{1}{2}$ in. thick. A common length for AB is 1 yd., the height of DE being also about 1 yd. Instead of the small piece of wood a tapered sole-piece extending the whole length may be secured to the base of AB.

For checking the gradient of a road an ordinary straight-edge and spirit level are very often used. If

the road rises or dips, a small piece of wood or sole-piece is attached to the straight-edge, as already described. Sometimes instead of the base-piece a small triangular piece of wood, in which the spirit level is embedded, is screwed to the upper edge of the straight-edge.

From the foregoing it is evident that by "distance" in § 53 is meant *horizontal* distance, not distance measured along the slope or incline. Fig. 92 makes it quite clear.

CHAPTER XXII

WORKING THE COAL—(*Continued*)

The Shaft Bottom—Driving and Securing the Main Roads

144. **The Shaft Bottom.**—The shaft (or pit) bottom (fig. 93) is a very important place. Here all the men disembark from the cages after descending the shaft on their way to their work, and here they return after their day's labour is finished. All the fresh air required for the mine has to pass this part, some of it going in one direction and some in another. The full hutches arrive here from the workings and are sent to the surface in the cage, while the empty ones, after being taken off the cage, are dispatched into the workings to be filled in their turn.

The parts of the main roads, then, for a certain distance on each side of the shaft, it can be understood, require to be wide and high and strongly secured, and all things well planned to permit of the work being quickly and easily done. Several lines of rails are required, but next the shaft itself iron plates are laid to allow of the hutches being turned readily in any direc-

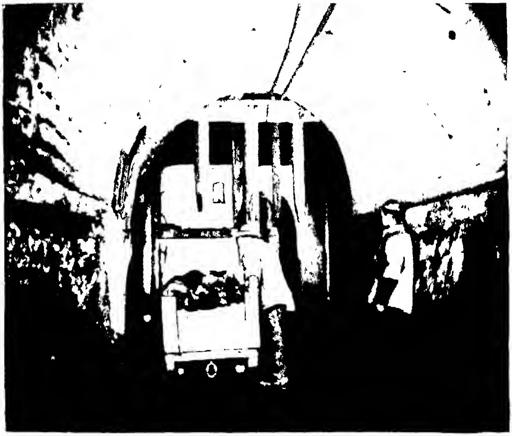


Fig 93 - An Inset at a Modern Colliery

tion. This arrangement of rails, &c., is sometimes termed the *shaft sidings.*

If the seam is not thick enough to give plenty of height, part of the floor is dug up or part of the roof taken down. Often the sides and roof (and sometimes the floor also) are secured by means of brick arching (fig. 93), and sometimes wood beams or iron or steel girders, stretching across the roof, are supported by walls of brick or wood built along each side of the road. In the latter case long pieces of wood, called *lofting* or *lagging* (another name is *cleading*), are placed longitudinally on the top of the beams or girders, extending from one to another. This is to prevent any rock material from dropping down between the beams or girders (see figs. 97, 98, for lagging).

145. **Dimensions of Main Roads from Shaft Sidings to Workings.**—There is, of course, less traffic on the part of the main roads from the shaft sidings to the workings than at the shaft bottom, and these parts, therefore, do not require to be either so wide or so high as near the pit bottom. Their dimensions are such as to suit the requirements of the mine, the width varying from about 6 to 12 ft. and the height 6 to 8 ft. As at the shaft bottom, if the thickness of the seam is not sufficient to give the required height, part of either the roof or floor is removed, whichever is considered best in the circumstances.

146. **Driving the Main Roads.**—In forming the main roads, or *driving* them as it is called, the tools used are picks, shovels, wedges, hammers, and blasting gear. The first step is to cut away the coal at the bottom, or any soft material under it. In doing this the miner lies on his side, or sits or kneels (fig. 94), and swings the pick backwards and forwards, hacking out a little of the coal or soft material with each forward stroke. This

process is known generally as *undercutting* or *holing* the coal, though in some districts it is termed *kirving*. It is very laborious work, and in the general extraction of the seam is often now done by machines. Machines are also sometimes used in the driving of the main roads. These will be dealt with in chap. xxv.

Sometimes the holing is done in a band of stone contained in the seam. When done in the seam itself it gives rise to a good deal of waste, as, of course, the coal produced in the holing is very small.

As the miner proceeds with the undercutting he moves from one side of the road to the other or across the face—the "face", as we saw in the preceding chapter, being the extreme end of the road, where the miner is at work. When he reaches the side of the road he shovels back the "holings" or dirt which he has produced and begins again.

After holing in this way for a short time the miner will be unable to work freely on account of the narrowness of the opening he has made, and, to give himself more room, cuts away part of the coal, or more of it if he has been holing in the coal. Then he holes farther in, the undercutting assuming the form of a large wedge (fig. 115). The exact depth of the holing depends on the nature of the seam, hard coals being undercut for greater distances than tender coals.

147. To guard against the coal falling down while it is being holed, *sprags* or *holing props* (figs. 94, 115, and 136) are set up along the face at distances not exceeding 6 ft. (General Rule 22). Six feet, it will be noticed, is the *maximum* distance the sprags can be set apart, but, as is evident from the rule, it may be necessary to have them closer together. In all cases they must be carefully set up at the distances required.

The kind of sprag used depends on the nature of the

coal. Those shown in fig. 136 are the ordinary form, the "cocker sprag" (fig. 115, 94) being employed where the coal is tender and liable to break down. In this case a bar of wood is placed across the face and supported by sprags and struts in the way shown. In addition to the "cocker sprags", under or ordinary sprags may be used, also other arrangements suited to the conditions of the seam, the object in every case being to support the coal and make the operation of holing as safe as possible for the miner. (See also "Dirt partings", § 61.)

When the undercutting has been completed the sprags or holing props are cautiously removed and the coal taken down. In some cases it is possible to get down the coal by the aid of the pick alone, or with the addition of hammer and wedge, but usually in driving a main road the coal has to be "blown down" by explosives. Where blasting is necessary one or more holes are bored in the seam near the roof, charged with the explosive substance, and then fired.

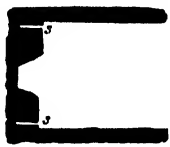


Fig. 95 - s, s, Shot Holes. Centre removed

If, say, three shots are required, the first will be used to blow or burst out the centre of the coal face, and the other two to break down the parts left on at the sides (fig. 95). The two side shots will not require so much explosive substance as the centre one because, as has been seen (§ 126), the latter "unkeys" the face and makes the work of the side shots less (or it gives "cut" to the side shots). The centre shot is sometimes called a "burster", "sumper", or "sumping shot".

Sometimes, before attempting to take down the coal, whether by hand (*i.e.* pick, wedge, &c.) or explosives, a vertical groove is cut in it at one side of the road, from roof to floor, in to the back of the holing (fig. 96). This

is termed "nicking" or "shearing" the side. Its effect is to unkey the face and render the use of a sumping shot unnecessary. Thus where the side is nicked two shots might be able to do the work of three where it is not nicked. But shearing, like holing, adds greatly to the laborious part of the miner's work. It is done with the pick, the miner sometimes standing (if the height of the seam permits of it) and sometimes kneeling, or occupying a recumbent position, during the process. The coal produced, too, is very small. In some cases both sides of the road are nicked.

Fig 96.—Side Nicked

A line of rails is laid down as the face advances, and along this the hutches of coal are taken to the shaft bottom. Provision has also to be made for the ventilation of the face (fig. 150)

148. **Stone Drifts.** — Sometimes a main road has to be driven through stone instead of in the seam. The excavation is then termed a *stone drift*, though other names, such as "stone mine" and "mine" are also used.

A stone drift is more expensive to drive than a road through the coal. This is because the stone is harder than the coal, and usually of no value. Most of the cutting work has to be done by explosives, "sumping" or "breaking-out" shots being fired, and then "side" or other shots. Great skill is necessary in fixing the position of the shot holes, in order that the smallest number may suffice, thus saving not only explosive substance, but the time and labour of boring a large number of holes.

The holes are drilled either by hand (*i.e.* hammer and drills) or by a machine. Hand-drilling machines (figs. 137–8) are generally employed; but often where the

drift is long and the stone very hard, machine drills, worked by compressed air or electricity, are used.

The shots having been fired, the sides and roof are prepared for the reception of timber or other supports, great care being taken to remove all overhanging and loose stones.

149. **Securing the Main Roads.**—As the roads advance they usually require to be secured to prevent falls of

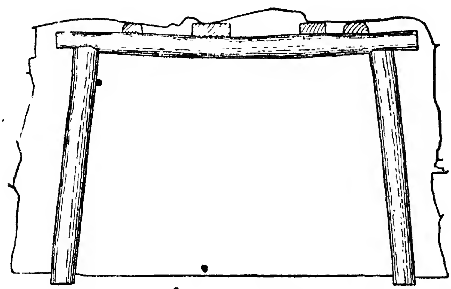


Fig. 97 —Set of Timber (termed in North of England a "Pair of Gears")

roof and sides, and this is done by means of timber or by iron or steel girders, some parts, if necessary, being arched.

150. **Timbering.**—The method of timbering depends on the nature of the roof, sides, and pavement. A full set of timber consists of three pieces, a *crown* (other names are *crown-tree*, *collar*, *cross-bar*, or *bar*), and two *props* (also called *legs*, *posts*, or *trees*). The crown extends across the road and is supported by the props, one at each side of the road (fig. 97). The centre of the crown is the weakest part; and in order to reduce the span, or length of crown unsupported, thus enabling the latter to sustain a greater pressure before collapsing, the props are

placed as shown, a few inches inwards from the extreme ends of the crown, and with the tops inclined a little towards each other. Usually, on account of the nature of the roof, the crowns require to be lagged (§ 144 and fig. 97), and sometimes laggings are necessary at the sides also—between the props and the strata (fig. 98). In all cases care must be taken to see that the crown or laggings fit tightly against the roof, lest the latter settles down suddenly and displaces the timber.

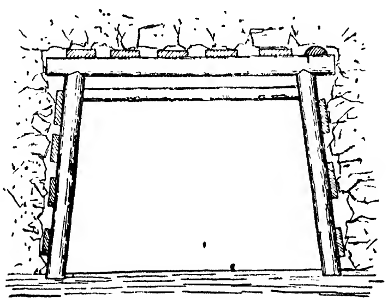
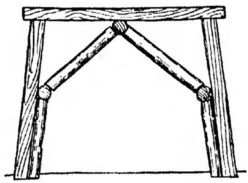


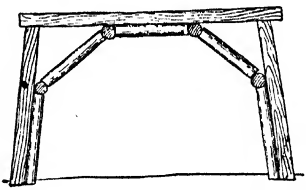
Fig. 98.—Timbering for Top and Side Pressure

Where there is a danger of the props being pushed out by the strata, as when the use of side-lagging is necessary, the crown is notched and the tops of the props shaped to suit. Sometimes other means are adopted. Where the side pressure is very great a piece of wood termed a "strut" is placed between the props, underneath the crown (fig. 98), thus effectually preventing them from being pushed inwards.

Where the floor is soft the ends of the props are rested on an inverted cross-bar, and where it is hard, so that the prop is liable to be broken by the pressure

of the roof settling down on the crown, "soles", "sole-pieces", or "sole-trees", are used. These are small pieces of wood placed under the props; by yielding or giving way to the pressure they prevent the props from being broken. Instead of a sole-piece the end of each prop is sometimes rested on a small heap of dirt placed in holes made in the pavement for the purpose. Also in some mines the props are tapered at the lower ends, the sharpened ends yielding to the pressure and "burring" or "fuzzing" up, instead of the prop breaking.





Figs. 99, 100.—"Double" or "Street" Timbering

When the sides are hard, and the roof only needing support, the legs are dispensed with, a hole being made in the one side of the road and a groove in the other, and an end of the crown inserted into each. This is sometimes termed "needling". Where one side only is hard, "half-needling" or "half-timbering" (fig. 116) may be adopted, one end of the cross-bar being supported by the strata and the other by a prop.

Figs. 99–100 show methods of "double-timbering" not much used in this country. They are employed to resist heavy pressures. The horizontal pieces are held in position by wire lashings until the supporting pieces have been got into their places. The crown, it will be ob-

served, is supported at its centre or weakest part. Sometimes in wide roads, timbered in the ordinary manner with props and crown, a third leg is used to reduce the unsupported length of the latter. Other means are also adopted for the same purpose.

Single props are likewise used to support the roof (figs. 101, 115). In this case a piece of wood, termed a "lid", "bonnet", or "cap", is placed between the roof and the top of the prop. The lid, by covering a larger area of roof than would the top of the prop, spreads the resistance of the prop over a greater extent of surface. It is also compressed as the roof sinks down, thus having the same effect as a sole-piece, or, to a smaller extent, of the tapering at the lower end of a prop. In setting props care must be taken to place the lid so that it bears evenly against the roof and to have the prop at the centre of the lid. A lid smaller than the top of the prop must not be used, as that tends to split the prop when the roof pressure comes on. Single props are used mostly in the working places of mines.

151. **Wood Pillars, Chocks, or Cogs.**—These (figs. 110, 136) are employed both in the main roads and working places. They consist of layers of wood built up from floor to roof, the timbers of each succeeding layer crossing those of the layer below at right angles. When intended for permanent use, as in the main roads, dirt is filled into the interior of the cog as it is built up, and pieces of rock material inserted into the spaces between the timbers. In the working places the cogs have often to be removed, and to facilitate this the bottom timbers are laid on a small heap of rubbish. When necessary to "draw the cog" the rubbish is first scraped out from below it. Cogs vary in size from about 3 ft. square upwards. They are built of old pieces of wood, such as broken timbers, old railway sleepers,

Fig. 101 Setting Timber Props

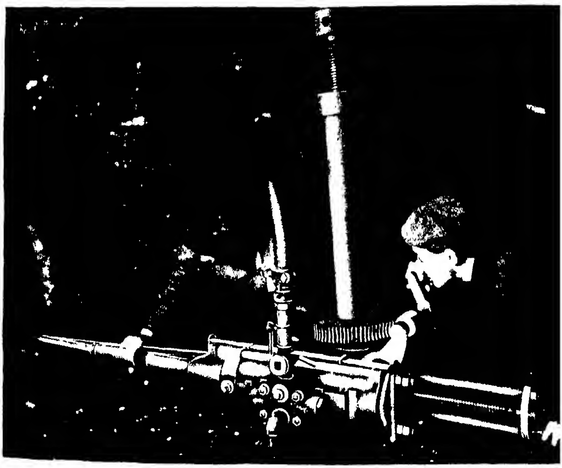


Fig. 110 Ingersoll "Radial" Machine

&c., and are capable of withstanding very great pressure.

152. **Kinds of Timber Used in Mines.**—The kinds of timber commonly used in mines are fir, pine, and larch. These are found to be well adapted for pit purposes. Fir and pine are imported extensively from Norway and Sweden. In positions where great strength is required oak is employed, but it is expensive, and when in small pieces difficult to shape.

153. **Preservation of Timber.**—Timber in mines is liable to decay, and in order to prolong its life, and save the cost of labour in constant renewals, it is sometimes subjected to certain kinds of treatment before being taken underground. Many different preservative methods have been tried, one being to soak it in boiling water in which common salt and a substance called chloride of magnesium have been dissolved. This is termed the *Aitken process*. Another method is that known as *creosoting*. Creosote is an oily, colourless liquid obtained from wood tar. It is forced into the pores of the wood intended to be preserved, the air being first extracted.

154. **Iron and Steel Supports.**—These are stronger and more durable than timber supports, and have in many instances practically superseded the latter in the main roadways of mines. In some cases iron or steel girders are supported on wooden props or brick walls, while in others the props as well as the crowns are of steel (fig. 102). To prevent the props from being displaced, iron or steel shoes or chairs are used. These fit on to the top of the props, holding the girder in position. Sometimes other methods are adopted. Iron and steel supports cost more than wood, and consequently are less used in the working places where they would be liable to be lost.

155 **Arching Main Roads.**—Fig. 103 shows a method

of securing a main road by brick arching. The roof semicircular in form, is built on straight side walls. This is a common shape, but sometimes other forms

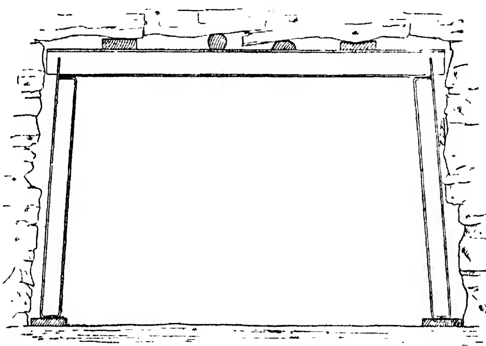


Fig 102 - Steel Props and Bar

are preferred. Arching is very expensive, and is only adopted where the pressure is great and the road difficult and costly to maintain. The thickness of the walling is from about 9 to 24 in. according to circumstances. Sometimes where the floor is bad it is necessary to build the side walls on an "invert" or inverted arch. No hollow spaces are left behind the walling (§ 150), and all timber used in supporting the strata while the arch is being built is removed.

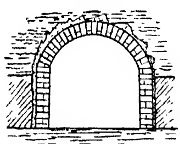


Fig 103 —Underground Arch

To help to preserve the arch when the pressure comes on to it, a lining of soft material, as sand, is placed between the walling and the strata.

CHAPTER XXIII

WORKING THE COAL—(*Continued*)

Methods of Working the Coal—The Bord-and-pillar (or Stoop-and-room) System—Cleat—Thrust and Creep

156. **Methods of Working the Coal.**—Miners use the expression "working the coal" when referring to the extraction of the seam. "Method of working the coal" means, then, the way or mode in which the seam is extracted.

Now there are two main methods or systems of working coal. Their names are *bord and pillar* (called in Scotland *stoop and room*) and *longwall*. Other names applied in England to the bord-and-pillar system are *pillar and stall* and *post and stall*. In Scotland the only term used is "stoop and room", and Scottish readers of this book should substitute that name for bord and pillar or other English term. As already learnt (§ 139), "stoop" is another name for pillar, as also is "post". "Bord", "stall", and "room" likewise mean one thing, namely, roads or working places driven in forming the pillars. The system known as "longwall" is termed so both in England and Scotland.

157. **The Bord-and-pillar (or Stoop-and-room) System.**—As implied by the name of this system, and as shown by fig. 104, the coal is extracted in two stages or operations. In the figure the rectangles represent pillars of coal, the narrow open spaces between being passages or roads. Now the roads must have been driven at right angles to each other to form the pillars, and the coal taken out in the process represents the first portion of the seam excavated. Afterwards the pillars themselves are worked out (the part of the mine from which the

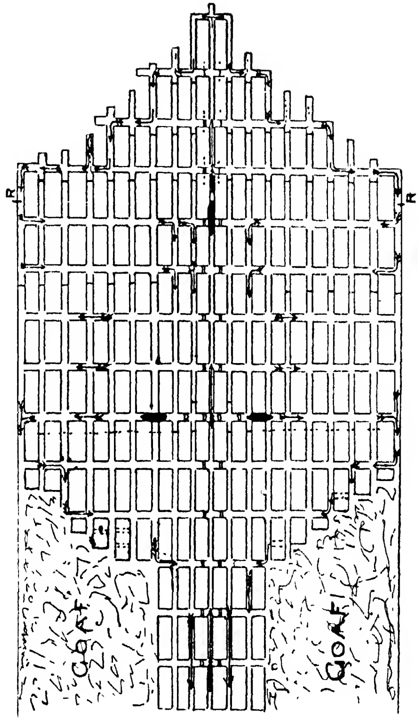


Fig. 104.—Illustrating Method of following up "Whole" with "Broken" in Bord-and-pillar System of Working Coal, and the Ventilation of the Workings

REFERENCE TO DETAILS. Air currents Doors, D Regulators, R.
STOPPINGS. Canvas Wood Brick or stone
Flats or sidings in which the coals are brought by Putters

coal has been entirely extracted being called the *goaf*, fig. 104), and this constitutes the second operation in the removal of the coal.

We see then that the procedure in the bord-and-pillar system of working coal is simply this: driving roads or working places at right angles to each other through the solid, thereby dividing the seam into pillars (first operation); extracting the pillars (second operation). Driving the working places through the solid coal is termed "the first working", "working the whole", or "working the solid", while in contradistinction to this the extraction of the pillars is known as "the second working", "working the broken", or "working the pillars". In Scotland the extraction of the pillars is always referred to as "stooping". The goaf, also termed *gob* and *waste*, is filled with fallen roof-rock. The pillars are to support the pressure of the strata above, and after the coal has been worked out, it would be impossible, even if desirable, to keep up the roof, and so, as the pillars are gradually extracted (in the way presently to be shown), the timbers used to support the roof are withdrawn and the rock allowed to fall.

158. **Sizes of Pillars.**—It will be noticed that the places in the first working are very narrow in relation to the dimensions of the pillars. This is because only from about 8 to 30 per cent of the seam is taken out in the first working, the remainder being contained in the pillars. The excavations in the first working may be 2, 3, 4 or more yards in width, while the pillars may be as much as 60 yd. square, or even more. Now extracting the pillars is really very dangerous work—much more dangerous than working the solid coal—and therefore it might be thought that it would be better to take out more of the coal in the first working and leave smaller pillars. The result of that, how-

ever, would probably be that a large proportion of the seam would require to remain unexcavated, and that would be a great loss to everyone. In the early days of coal mining the pillars were made smaller, but the miners then did not attempt to extract them. They merely took as much coal from each pillar as they

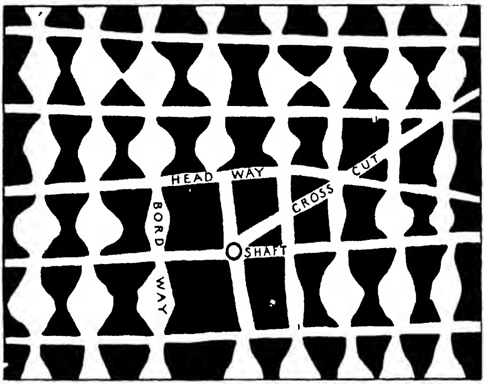


Fig 105 – Plan of Coal Mine, showing "Robbed" Pillars

could with safety (termed "robbing the pillars", fig. 105), leaving the remainder unworked. In modern times, with our more advanced mining methods, these old workings have in many cases been opened up, and the best of the "robbed pillars" taken out. It is from the pillar workings, then, that the larger part of the output in the bord-and-pillar system is obtained, but the pillars are made large because it is necessary to do so. The actual size depends on many things—depth from surface, &c.—as in the case of the shaft pillar,

and is a matter of experience, the dimensions varying in different seams. In shape the pillars are square or rectangular, and some actual sizes are 20 yd. square, 30 by 20 yd., 30 yd. square, 40 by 30 yd., 44 yd. square, 50 yd. square, &c.

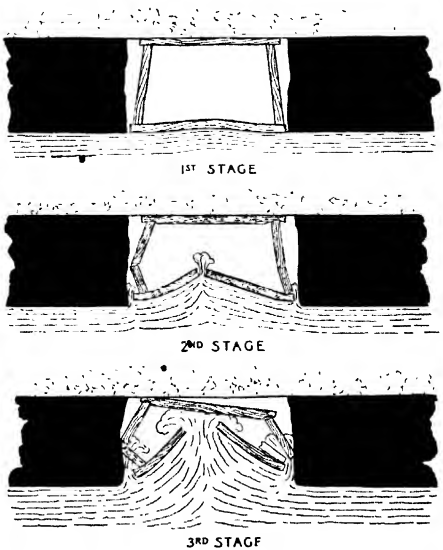


Fig 106. – Diagram of "Creep" in a Seam with a Hard Roof and Soft Floor

159. **Thrust and Creep.**—In fixing the size of the pillars endeavours are made to guard against *thrust* and *creep.* Thrust occurs when the pillars are small and the roof and floor hard. The pressure of the strata above being greater than the pillars are able to withstand, the coal

is crushed between the roof and floor. Other appropriate names are *crush* and *sit*. As the result of thrust the coal may be rendered unmarketable.

Creep is a gradual upheaving or rising of the floor whereby the timber is broken and the roadways ultimately choked up (fig. 106). It occurs where the floor is soft, the pressure of the roof on the pillars forcing the soft material into the roadways.

In some seams it is very difficult to prevent creep. Its occurrence is assisted by the presence of water. Once begun it is almost impossible to stop it. The result of creep may be the entire loss of the coal, and in any case it greatly adds to the difficulties and cost of working.

160. **Laying out the Workings.**—By this is meant the method of arranging the workings for the extraction of the coal. Some definite plan or procedure must be followed. From fig. 104 it will be seen that the working places in the solid coal are started off the main roads, and one method of laying out the workings is to continue the solid places right through the seam until the whole of the latter has been formed into pillars. The pillars are then taken out, beginning with those farthest from the shaft. Another plan, very often adopted, is to begin the extraction of the pillars, a safe distance from the shafts, soon after they have been formed. In this second way the work of removing the pillars follows up the first working (fig. 104), and the method is therefore termed "following up the whole with the broken". It has great advantages over the system in which the extraction of the pillars is not commenced until all the solid places have reached the boundary, the coal being got in better condition and with less trouble and expense, and the supervision and ventilation of the mine simplified. When the pillars stand for a large number

of years, as they must do where all the solid places are first driven, the coal becomes much crushed by the weight of the roof, and the roof itself broken down in many of the stalls. By following up the whole with the broken there is not time for these things to occur to the same extent; besides, the mine workings extend over a smaller area.

When the pillars are taken out, the roof-rock, as we have seen, is broken up, falling and filling the waste, and, where the whole is followed up by the broken, care has to be taken to keep the second working a safe distance behind the solid places and not to take out pillars too near the main roads.

In a third arrangement, termed the *panel system*, the mine is divided into "panels" or "districts", one panel being separated from another by thick barriers or "ribs" of coal. Thus we see there are three plans or arrangements by which the workings in the bord-and-pillar system may be found to be laid out. The panel system was introduced about the beginning of the last century by Mr. Buddle, a celebrated mine overseer.

161. **Driving the Places in the Whole Coal.**—The places in the first working are driven in the same manner as the main roads, the coal being holed and spragged, then taken down, and the roof secured with timber. In holing the coal, hand labour or coal-cutting machines are employed. Generally, in breaking down the coal, explosives are necessary, these being used in the same way as we learnt in connection with the main roads, sumping shots being fired or the sides nicked. In securing the roof full sets of timber may be required, with, in addition, props and lids at one or both sides, according to the width of the place and the nature of the roof. In some cases only cross-bars and props are necessary, while in others props with lids may be sufficient. In others

again, especially where the places are narrow, timbering may be unnecessary. Generally, however, timber of some description is required, and in every instance the place must either be safe or made safe, every precaution being taken to guard against accident. (See chap. xxv.)

162. **Cleat.**—In working the coal, account is taken of

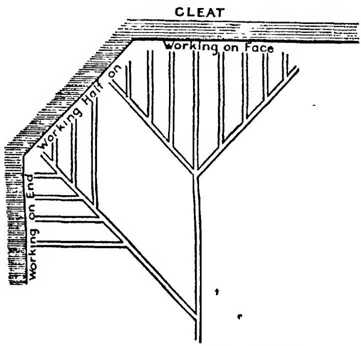


Fig 107.—To illustrate Direction of Face with reference to Cleat

the "cleat". This, it has been seen (§ 104), is the name given to the better developed of the two sets of natural joints or planes of division found in coal, the term "face" being also used and the term "end" applied to the less perfectly developed set of fissures running at right angles to the cleat. When, therefore, the working face is (1) advancing parallel to the main cleat (fig. 107), the coal is said to be worked "on the face" (other terms are "on the plane" and "on the back"); (2) if at right angles to the cleat, that the coal is being worked "on end"; and (3) if at an angle of 45 degrees with the cleat, that

the coal is being worked "half-end", "half-plane", or "half-on". The coal is worked most easily "on the face" or "plane", hence in the bord-and-pillar system the places are sometimes made wider in that direction, and narrower "on end" (see next paragraph). Also the places going "on the plane" are sometimes driven a longer distance than those "on end", thus making the pillars longer in the direction of "on the plane".

163. **Bords, &c.**—In the second paragraph of the present chapter "bords", "stalls", and "rooms" were described as "roads or working places driven in forming the pillars". These terms have not been used since, because they are purely local names, and also because bords are the roads or working places driven in *one direction only*, other names being given to the excavations at right angles to the bords. We are now in a position to understand that the bords are the working places driven "on the face", the terms *headings*, *headways*, or *walls* being used to denote the excavations at right angles to the bords or "on end" (fig. 108). Often the direction of the bords is referred to as "bordways", "bordway course", or "bordway direction", and that of the headings as "headway course", &c. Bordway direction, then, is the direction in which the coal is most easily worked (preceding paragraph), hence the bords are usually made wide, 4 to 5 or more yards, though sometimes narrow, the headings or wallings being about 2 yd. in width. Where the cleat is not well developed the headings may be of the same width as the bords.

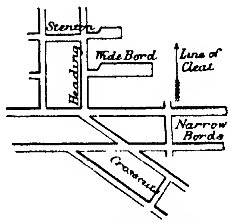


Fig. 108.—Working Places in Bord and-pillar System

A *stenton* is a passage driven between two roads for the purposes of ventilation, and "cross-cuts", as shown in fig. 108, are excavations driven at an angle to the bords and headways.

164. **Extracting the Pillars.**—A pillar, it might be thought, would be extracted in one operation, beginning

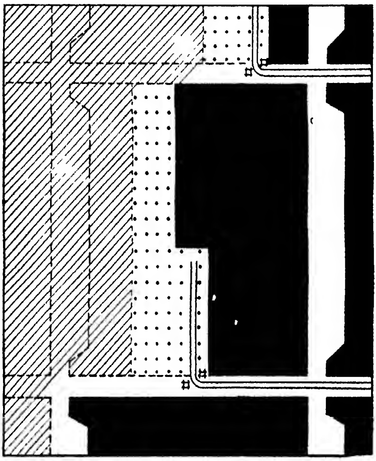


Fig. 109.—Extracting the Pillars

at one side and gradually excavating the whole mass. This is sometimes done, the waste being filled up, or "packed" as it is called, with rubbish. Extracting the pillars in this way is termed the "longwall method", and will be better understood when we have learnt about longwall. It is not a method that can be always easily applied, and so the more general way is to take out the

pillar slice by slice until it has been entirely removed (fig. 109). The slices thus cut away are termed *lifts*, *cuts*, or *juds*. The width of a cut may be as little as 8 ft. or more than 6 yd. It depends on local conditions, such as the nature of the roof, &c One lift only may be removed at one time, or two kept going simultaneously on different sides of the pillar or otherwise, as may be considered best. The exact method of extracting the pillars depends on the circumstances; and different methods may be found in operation in the same colliery. In every case it is desirable to have the lifts as short as possible, and to secure this large pillars are sometimes divided, or "split" as it is termed, by driving places through them, the smaller pillars thus formed being then removed in slices. The last portion of the pillar is the most dangerous to remove, and requires to be extracted as quickly as possible, the roof being very strongly timbered.

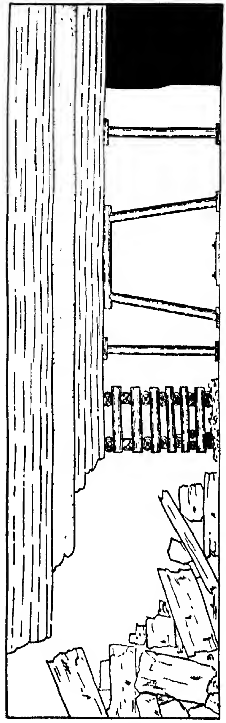


Fig. 110.—Section across a Lift in Broken Workings

165. **Timbering the Lifts—Drawing the Timbers.**—In driving the lifts, the waste being on one side, it is plain

that the roof must be well timbered (fig. 110). A large number of crowns and props, and props with lids, is required. Cogs are also sometimes necessary, being built either only at the start of the lift (one on each side of the tramway), or in a row on the side of the tramway

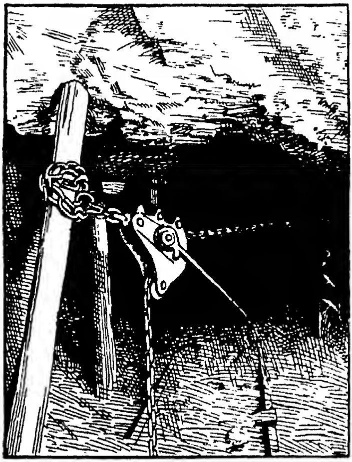


Fig 111.—"Hardy" Pit Prop-puller. The prop marked × × × is to be withdrawn

next the goaf. Sometimes, instead of the row of cogs along the edge of the waste, dry stone walls are built. The tram rails are, of course, laid as the face of the lift travels forward.

When the lift is finished the tram rails are removed and the timber withdrawn. Sometimes the timber is not withdrawn until the completion of the following lift (fig. 109). It is taken out with the twofold object

of saving it for further use and allowing the roof to fall (§ 157). Drawing the timber of a lift is very dangerous work, and requires the greatest care and skill on the part of the operators.

The timber nearest the edge of the goaf is first removed. The operator may use an appliance termed a "prop-puller", as illustrated in fig. 111 (another appliance is the "Sylvester Prop-withdrawer"), but the more general method is, if necessary, to cut away the prop at the top or bottom with an axe, and then knock it out with a hammer provided with a long handle. The long handle enables the miner to stand under the crown of an adjacent set of wood, out of the way of the falling debris; but the whole operation is, nevertheless, a very dangerous one. For recovering the timber after it has been knocked out, a tool, consisting of a long rod with a handle at one end and a spike at the other, there being a hook near the spike end, is used. This tool, sometimes called a "jobber", is also used for pushing or knocking out the timber.

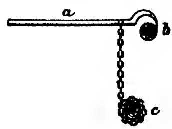


Fig 112.—Ringer and Chain

a, Lever; *b*, fixed prop used as fulcrum; *c*, prop with chain around to be withdrawn

For drawing out the timber an appliance called a *ringer and chain* (other names are *dog and chain* and *gablock and chain*) is also employed. This (fig. 112) consists of an iron rod or lever about 6 ft. long, having a curved end, near to which a chain is attached. It is used as shown, the hook or fulcrum end of the lever pressing against the fast prop as the lever handle is pulled back. The "Sylvester Prop-withdrawer" and "Hardy Prop-puller" are improvements on the ringer and chain. They can be used for other purposes besides drawing out props. In fiery mines great care has to

be taken in drawing the wood, as firedamp may be contained in the waste and forced out into the workings when the roof falls.

CHAPTER XXIV

WORKING THE COAL—(*Continued*)

The Longwall Method—Comparison of Bord and Pillar (Stoop and Room) and Longwall—Single and Double Stall.

166. **The Longwall Method of Working.**—In this system the coal is taken out in one operation, not in two as in the pillar-and-stall method. In one application, called *longwall retreating* or *longwall working home*, roads are driven right through the seam to the boundary and the coal worked back towards the shaft. Thus the goaf or waste is left behind, each day seeing the working places a stage nearer the shaft bottom. This method is, however, seldom adopted. The driving of the roads through the seam adds to the cost of starting the colliery, and the more general way is to begin the extraction of the coal as soon as the shaft pillar has been formed, the workings thus advancing from the shaft pillar to the boundary, and each day seeing them farther away from the shaft bottom. The goaf or waste is thus *between* the working places and shaft pillar. This is known as *longwall advancing* or *longwall working away* (fig. 113).

167. **Longwall Advancing.**—The driving of the main roads is proceeded with, and off these, as they advance, the roads for the excavation of the coal are started (fig. 113). The latter roads, thus leading into the coal-face, are termed "face-roads" and "stall-roads". They

are also called "side-roads" and "gob-roads", the latter name being used because the roads pass through the goaf or waste. In England the term "gate-ways" or "gate-roads" is also used, the main gate-ways being sometimes called "mother-gates".

The seam is opened out into long "walls" or "faces", these being divided into shorter "walls", called also

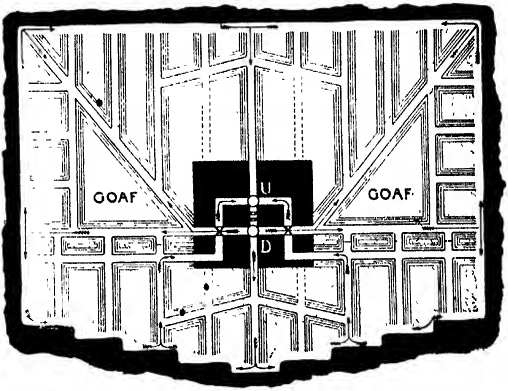


Fig. 113.- Illustrating Longwall advancing with straight and stepped faces, shaft pillar, and ventilation

D, Downcast shaft, U, Upcast shaft; Air currents; Wood doors Air crossing; Canvas doors. Gateways, lines indicate the packwalls of stone.

"stalls" and "places". In each place two or more men work, and to each place there is a separate "face-road". (See top and sides of fig. 113.) The pressure of the roof or "weight" might be too great if the face were in a long straight line, and the places may have to be "stepped", that is, one kept a certain distance in advance of another (see bottom of fig. 113).

The distance between the face-roads depends on the thickness of the seam and other conditions. Where the height is sufficient the tubs are sometimes taken along the face (fig. 114). Where it is not, the coal is "thrown" to the "road-head" and there put into the tubs (§ 173).

As the face-roads become longer, owing to the excavation of the coal, they are cut off by other roads called "slope-roads", "cross-roads", "cross-gates", &c. These reduce the distance the coals have to be drawn and the length of roads to be kept open (see top and bottom of fig. 113, the dotted lines show roads cut off). The new face-roads are carried forward from the cross-roads—or cross-gates, &c.—and will be cut off by other cross-roads when they begin to get too long.

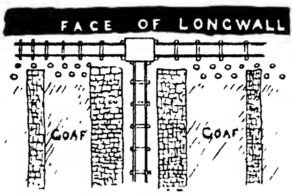


Fig. 114.—Longwall. Plan showing Packs, &c., and Tramroad laid along Face

The coal being all taken out as the faces advance, something has to be put in its place to support the roof. For this purpose *packs* or *buildings* are employed (figs. 114, 116), props, and sometimes chocks also, being used as temporary supports.

The packs or buildings are stone pillars. In putting them in, dry stone walls are built along each side of the road, from floor to roof, and also along the face, and the space inside filled up tight (figs. 114, 116). Usually the pack-walls do not extend from road to road; the space thus left is stowed with rubbish.

The material for building the packs is obtained by blasting down the roof of the road-ways (termed *ripping* or *brushing*) for a thickness of several feet

(fig. 116) or forcing up the floor, whichever is most suitable in the circumstances. The rubbish produced in the excavation of the coal is also utilized; and in some cases material has to be brought from the surface or from another part of the seam In building the face pack-wall a sufficient space is left between it and the coal to enable the miner to work freely, and as the coal is excavated and the face travels forward the temporary supports are set up. Then another pack is built, and so on, the packs thus forming a continuous line (fig. 114). The operations of blasting the roof or floor and building the pack-walls are done after the coal-getters have ceased work. The blasting of the roof or floor in the roads gives height for the trams, but the roof soon presses down the packs and may break the timber in the roadways. The packs therefore have to be made as solid and strong as possible.

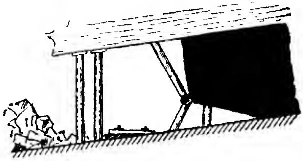


Fig 115.—Section across Face of 5-ft Seam worked by Longwall

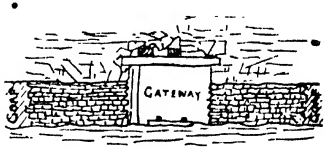


Fig 116 —Face-road (or Gate-way, &c) with Roof ripped down to make Height

The coal is removed in the way already learnt, the weight of the roof assisting in breaking it down, and in many cases rendering the use of explosives unnecessary. The greatest aid is obtained from the action of the roof when the coal is being worked "on the face" or "plane" (§ 162), but this direction may result

in much small if the coal is soft, and working "on the end" may be necessary. Where both sets of divisional planes are good, and the coal soft, "half on" may be most suitable, and that may be the case also if the seam is steep, or the cleat not well developed. Thus the direction of the face is influenced both by the cleat and inclination of the seam, and is in all cases chosen to suit the conditions. For the holing of the coal coal-cutting machines are often employed, and in thin seams *coal conveyors* (§ 173) are sometimes used, these carrying the coal along the face to the roadhead and discharging it there into the trams.

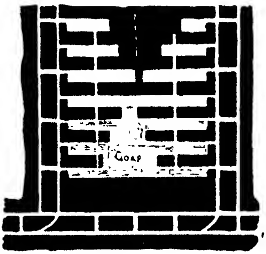


Fig 117 - Single stall Working

168. **Comparison of Bord and Pillar and Longwall.**—From the description of these two systems it will be seen that the longwall method is simpler than the bord-and-pillar. It is also safer than working the broken, and the mine is more easily ventilated. It is, however, not suitable in every case, and the bord-and-pillar or other system has to be adopted.

169. **Other Systems.**—Besides the bord-and-pillar and longwall systems other modes of extracting the coal are in use. Special measures require to be taken for the excavation of steep seams, of seams close together, and also of very thick seams. In South Wales systems called *single- and double-stall* (figs. 117, 118) are in use, while a method practised in the working of the Ten Yard Coal of South Staffordshire is known as *square work*.

In *single- and double-stall*, headings (the roadways running to the top of figs. 117, 118) are driven off the levels at intervals of 100 or more yards. The stalls are set away off the headings, a pillar or rib of coal being left between each pair. After the stalls have advanced as shown, the coal on each side is opened up and the pillars worked back towards the headings. Packs are formed in the middle of each stall.

In single stall, it will be seen, a single road is started off the heading and then opened out to form the stall; in double stall two roads are driven off the heading and the stall formed by connecting them. The coal left between the stall and the heading is to protect the latter, and is removed after the ribs have been worked out. In fig. 117 each stall is seen to be joined to the one next it by a small passage parallel to the heading. This is for the air to pass from one stall to the other. In double stall the air passes to the face by one road and out by the other.

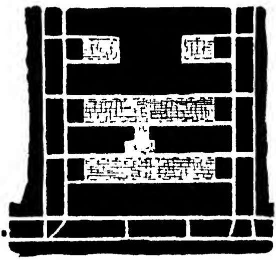


Fig. 118.—Double-stall Working

Sometimes in single stall the stalls are not set away right and left from the headings as shown in fig. 117, but only from one side, being then driven to within a few yards of the next heading, and sometimes, both in single and double stall, no pillars are left next the headings. Instead of each pair of headings shown in the figures a single wide heading is sometimes driven, the centre being packed in the same way as the stall.

CHAPTER XXV

WORKING THE COAL—(*Continued*)

Coal-cutting Machines—Underground Coal Conveyors—Approaching Old Workings—Timbering.

170 The present chapter is the last on "Working the Coal", and the first subject to be studied is **Coal-cutting Machines**. These, we have seen, are sometimes used in place of hand labour for under-cutting the coal. They are of different types, some (termed generally "heading machines") being adapted for working in narrow places such as levels and headings and the solid workings in the bord-and-pillar system, and others (called generally "longwall machines") for holing the coal at longwall faces.

171. **Heading Machines.**—Heading machines are of different forms, one, called the *Stanley*, designed for driving roads, dispensing with holing, and others holing the coal and shearing the sides, and even, if required, boring holes.

The Stanley heading machine is what is known as a *rotary* machine, the "cutter" or "boring head" being made to revolve and cutting an annular groove in the coal as we saw is done in diamond boring. The solid coal is afterwards broken out by the aid of wedges.

Radial (fig. 119, p. 150), *Siskol*, *Little Hardy*, and *Little Diamond* are names of *percussive* heading machines. These machines are used in the working places of the bord-and-pillar system as well as in the driving of roads. They are also sometimes employed in conjunction with longwall machines. They are worked by compressed air, the operator directing the cutting bit in a horizontal direction when holing and in a vertical direction when

shearing; the cutting bit is also advanced as required. A large number of blows is struck per minute.

Some percussive machines are mounted on wheels or on a special carriage, sometimes, therefore, receiving the name "wheel machines". The machines named in the preceding paragraph are attached to upright extension rods or standards (fig. 119) and are accordingly sometimes termed "stand" machines. By means of the upright column the machine can be fixed at any height between roof and pavement, thus enabling it to hole at the level required, such as in a band of stone in the seam, and also to nick the sides. Another class of heading machine is known as the *chain machine*—referred to under "Longwall Machines".

Lads are sometimes employed to work heading machines and must study the particular machine well, mastering the details, and carrying out faithfully all instructions. The person or persons in charge of a machine and the machine itself really form one whole, the person being the brain and the machine the hands, so to speak. The "brain" therefore has to be ever on the alert to assist the "hands"; and has to take pride in helping the machine to do the best possible work.

172. **Longwall Machines.**—Longwall coal-cutters are now very common. As in the case of heading machines they are of several forms, namely, *disc machines*, *bar machines*, and *chain machines*.

Disc Machine.—This is the commonest type of longwall machine. Cutters are fixed at intervals round the outside edge of a horizontal disc (fig. 120). The mechanism causes the disc to revolve, thus undercutting the coal. The disc, then, is like a large horizontal circular saw working under the coal.

Bar Machine.—The *Hurd* machine, now called the *Pick-Quick*, is an example of this form. A tapered bar

(fig. 121) takes the place of the disc in the latter class of machines. The bar has a spiral thread running along it and the cutters are set on the thread or between, according to the width of holing required. It is made to rotate, thus undercutting the coal. Besides rotating, the bar has a to-and-fro movement—in and out of the cut.

Chain Machines.—In this form an endless chain is used instead of a disc or bar. The cutters are fixed to the chain, which is made to circuit under the coal.

As mentioned under "heading machines", chain machines are also used in narrow places, but the arrangement is necessarily different from that of longwall machines, the part carrying the chain forming a continuation of the machine and being made to move forward as the undercutting is done. One such machine is the *Jeffrey*. When one part of the face has been undercut the machine is shifted and another part commenced.

Longwall machines propel themselves along the face as they undercut the coal. For this purpose a rope passes from the machine to a pulley fixed some distance ahead, thence back to a small drum on the machine. The machine works the drum, coiling the rope on to it, and thus drawing itself forward. The rate of movement along the face is regulated to suit the nature of the undercutting. The machine travels along the face on rails, skids, or sledges. When it reaches the end of its journey it either cuts back again to the other end of the face or is "flitted" (as it is termed) back to the starting-point. Some machines are driven by electricity, others by compressed air. Special arrangements for timbering suited to the circumstances are required where coal-cutting machines are used. As the machine travels forward the coal is spragged; afterwards the sprags are

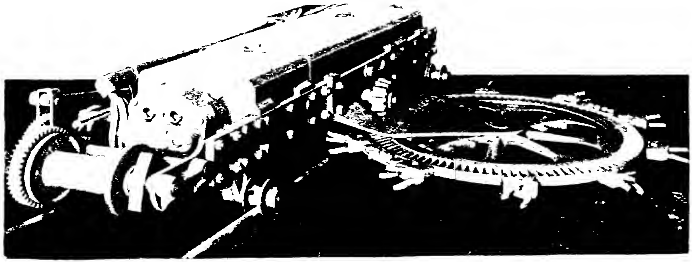


Fig. 120 — Diamond Coal-cutting Machine

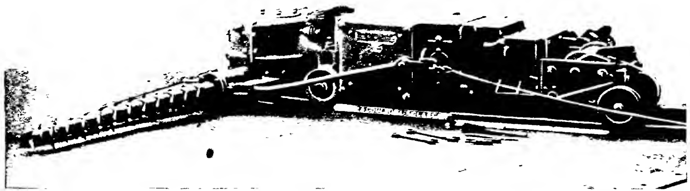


Fig. 121 — Hurd Electrical Machine

removed and the coal either falls or is taken down and put into hutches. For undercutting with machines the conditions must be suitable.

173. **Coal Conveyors.**—These are simply mechanical appliances for carrying the coal along the face to the roadhead and delivering it into the tub. As we saw in the preceding chapter, they are used in thin seams worked by the longwall method. When the coal has been taken down after being holed by machine or hand, it is loaded on to the conveyor, which conveys it as stated. The conveyor is moved forward with the face. As in the case of coal-cutting machines conveyors can only be used under favourable conditions. Where they can be employed they enable the face-roads to be driven at greater distances apart.

174. **Approaching Old Workings.** — Sometimes mine workings, in one or other of their many ramifications, approach some place or places containing such a quantity of water that if it were to enter the mine suddenly the result would probably be disastrous. To guard against this as much as possible certain precautions are rendered compulsory by the *Coal Mines Regulation Act* (G.R. 13). The "place" containing the water may be an abandoned working, the parts of which that are not closed by falls of roof having become filled up by water percolating through the rocks.

Fig. 122 illustrates this. On the left are the mine workings, and somewhere in front is the place (old workings) containing the water. Either one or two exploring drifts are driven in the direction of the old workings, or place containing the water. Where there are two it is in order that the necessary ventilating current of air may pass in by one and out by the other, hence they are connected at intervals (figs. 122, 150), the air travelling along the connecting passage from

the one to the other. Where there is only one drift a partition termed a *brattice* (figs. 123, 150) is sometimes erected, the air passing in by one of the compartments thus formed and out by the other. Sometimes the position of the old workings is not known with certainty, and great care has then to be exercised. Two drifts are not commenced unless the old workings are some distance off.

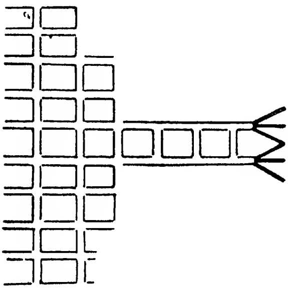


Fig 122.—Exploring Drifts advancing towards Old Workings

The boreholes are to ensure that the exploring drift or drifts shall not unexpectedly hole into the old workings, and that when the water is tapped there shall be a barrier of coal of sufficient thickness between the place containing the water and the drift. The actual thickness of barrier necessary depends on the pressure of the water and the nature and thickness of the coal, and the hole near the centre of the workings may therefore be kept in advance as much as 18 or 20 or more yards.

The borehole in front is generally called the "straight-on" hole, and the flank or side holes are sometimes termed "slope-holes". The latter are bored at intervals of about 2 yd., the direction of the hole making an angle of about 45 or 30 degrees with the centre line of the drift. Both flank and straight-on holes are about $1\frac{1}{2}$ or 2 in. in diameter.

When the pressure of water is great and the old

workings near at hand, only one drift is sent forward, side holes being sometimes bored at right angles; additional straight-on holes may also be necessary (fig. 123).

Other precautions are observed. The lengths of the boreholes must be checked by means of measuring rods prepared for the purpose, and tapered dry plugs for closing the hole when the water has been tapped kept convenient. Driving a plug into the hole is difficult where the pressure of water is great, and the boring is is therefore sometimes done through a pipe wedged into

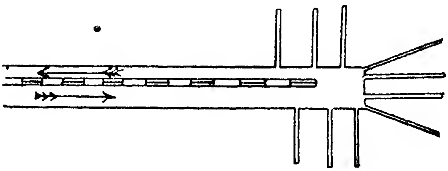


Fig 123.—Single Drift

the hole. This pipe has a valve which can be closed when the bore-rods have been withdrawn. Sometimes a special safety boring apparatus is used in which means are provided for the shutting off of the water when this has been struck.

Then only safety lamps must be used, as gas may be given off with the water, or the old workings may contain *a dangerous accumulation of gas or gases* instead of water. A spare safety lamp has to be kept burning a safe distance off, as the ones in use by the borers may be extinguished by a sudden burst of water or gas when the ground between the drift and the old workings has been pierced. For exploring work such as this very great caution is required on the part of the workmen. They must carry out all instructions care-

fully, and be constantly on the lookout for indications of water, or increase of amount, and for signs of gas.

175. **Timbering.**—The subject of supporting the roof and sides has already been well considered, but is of such great importance to a miner that one or two other things must be noticed here. In the mines of Great Britain far more accidents occur from falls of roof and sides than from any other cause, and there can be no doubt that with proper care many such accidents could be prevented. Thus many happen through delay in setting up necessary timber. The miner, being engaged in some work and not apprehending any immediate danger, thinks he will set up the prop, or do what is necessary by way of securing his safety, "in a minute"; but it is in that minute that the accident occurs. Or perhaps the miner forgets about the matter, and later on something happens which results in injury to others as well as to himself.

It is hoped that the young pitman who has had the matter brought before his notice will not be guilty of such fatal "putting off", and will severely condemn it in others, thereby doing much towards securing greater safety in mines. Sprags and props must be set up whenever required, no useless risk run, and everything done which will tend to secure immunity from accident (see also G.R. 21).

Great care and skill are necessary in setting up timber or other supports. Sprags must be placed so that they will support the coal without chance of falling or being pushed out, the tops or lids of ordinary or under sprags bearing properly against the coal, and the lower ends fixed in such a way as to prevent skidding. On ordinary props the lids must be placed so as not to injure the props (see also as to the packing, &c., of crown-trees, § 150).

Fig. 124.—Trying the Roof

Fig. 136.—Punching Hole for Powder Shot

In propping the roof in inclined workings the posts are not placed at right angles to roof and floor, as is the case in flat workings, but with the top inclined slightly uphill (fig. 115). This is because the roof tends to move downhill, and the props are thus carried into the position in which they are tightest or give most support to the roof. If the prop is placed at right angles to floor and roof in the first instance, it is moved into a position in which it gives less support to the roof, or is forced out.

Miners test the roof by tapping it (sometimes termed "jowling" it) with the flat part of a pick or a hammer or axehead (fig. 124). If it gives out a clear ringing sound it is considered "good"; on the other hand, a dull heavy sound indicates that it is "bad", and needing support. But a "good sound" cannot always be depended upon as implying that the roof is not likely to fall; indeed, it is through relying on this that many accidents have occurred. The roof often contains "slips", and these may cause it to drop down, although tested satisfactorily but a short time before. Slips, joints, and breaks must then be carefully looked for in addition to tapping the roof. Sometimes, however, it is quite impossible to see the slips until after the roof has come down, and accordingly the timber has to be placed so as to guard against these. It should be borne in mind that a good strong roof is often "treacherous".

It is in view of the difficulties in connection with securing the roof that what is known as *systematic timbering* has been recommended—the setting up of timber at fixed distances apart, and according to definite rules, the roof thus being supported in a regular way as the coal is taken out.

In connection with joints in the roof these sometimes coincide with the cleat of the coal, and, if close together,

and the coal worked "on face", may render the roof dangerous.

CHAPTER XXVI

SOME CHEMISTRY AND PHYSICS

Matter—Molecules—States of Matter—Expansibility and Compressibility of Gases—General Effects of Heat—Thermometer—Transmission of Heat

In the present and three succeeding chapters there must be considered certain things a knowledge of which is necessary to the proper understanding of "Explosives and Blasting" and "The Gases Found in Mines", the subjects which naturally follow "Working the Coal". Meanwhile, with regard to the general title of the chapters, it may be said that *Chemistry* and *Physics* are sciences—what they treat of will be stated in chap. xxviii.

176. **Matter.**—The first thing, then, of which we must acquire some idea is *matter*. Matter is defined as "that with which we become acquainted by means of our senses". Thus everything which we can see, feel, hear, taste, or smell is matter. An apple is matter because it appeals to all our senses; water is matter because we can see, hear, and feel it; and air is matter because we can feel and hear it. Everything, then, which affects one or more of our senses is matter. It is not possible to say what matter is, further than this—simply that everything on the earth (including the air surrounding it) consists of matter. Other names sometimes used for matter are *stuff* and *substance*.

Body.—Often in speaking of things, as, for instance, an apple, water, air, &c., the term *body* is used. Body

just means "some matter", or "a piece of matter". Thus the air, the earth, a stone, a piece of metal, &c., are all "bodies".

Molecules.—If we take any body, such as a marble, for example, and break it up into powder, we term the component parts of the powder *particles.* Now a *molecule* is the smallest particle of matter that can exist separately

No one ever saw a molecule, and no one ever can, not even with the most powerful microscope, so small is it. Thus some of the particles into which we have divided the marble may be so fine as to necessitate the use of a microscope to render them visible, yet the smallest of them would be much larger than a molecule. Nevertheless every kind of matter is believed to be made up of molecules, scientists having come to this conclusion from the evidence afforded by matter itself.

What we have to bear in mind here, then, is that all matter is made up of minute particles, called molecules, and that however finely we may divide a body there will always be a large number of molecules in the finest particle we have produced, molecules being so small as to be invisible even under the most powerful microscope known.

177. **The Three States of Matter.**—We have taken as examples of matter an apple, water, and air. Now an apple is termed a *solid,* water a *liquid,* and air a *gas,* and as every kind of matter is either a solid or a liquid or a gas, we say that *matter exists in three distinct conditions or states.* An apple, then, is an example of matter in the *solid state,* water of matter in the *liquid state,* and air of matter in the *gaseous state.* Other examples of solids are iron, stone, and wood; of liquids, oil, milk, and treacle; and of gases, coal gas, hydrogen, oxygen, and nitrogen. It will be seen in a future chapter that

air is not one gas, but a mixture, principally of oxygen and nitrogen, with small amounts of other substances.

General Differences between Solids, Liquids, and Gases.—It will now be well to observe how bodies in the one state differ generally from those in another state.

Bodies in the solid state, then, or *solids*, we can see, have a definite size and shape. Having a definite shape means that the molecules must continue to occupy the same relative position. If we wish to separate the molecules, or, in other words, break up the solid, we notice that we cannot do so without using a certain amount of force. With some solids, such as stone and iron, a great deal of force is necessary. Then, when the solid has been broken up, the parts remain separate.

It is altogether different in the case of bodies in the liquid state, *i.e. liquids.* A liquid resembles a solid only in that it has a definite size. It has no definite shape, as we can show by pouring water into bottles or vessels of different shapes, the water in every case adapting itself to the form of the bottle or vessel. Then we can very easily separate the molecules of a liquid, merely, for example, by passing our finger through the substance. As we move our finger through the liquid the separated particles rejoin. Clearly, then, the molecules of a liquid do not occupy any definite relative position like those of a solid, but simply roll or slide over each other when the liquid is disturbed. The surface of a liquid at rest, we should notice carefully, is *horizontal*, thus distinguishing it from particles of solids, such as sand, which can also be poured into a vessel.

A liquid which is thick, like treacle, is termed *viscous* or *viscid.* Some substances, such as jelly, are neither distinctly solids nor liquids.

A *gas* (or body in the gaseous state) departs in a

greater degree from the solid state than does a liquid, in respect that it has neither definite size nor shape. The molecules of a gas do not remain in contact, as do the molecules of a liquid, but tend to move away from each other. Hence a gas can only be kept in a closed vessel, and no matter how large the vessel or small the amount of gas the latter will always completely fill the vessel.

178. **Expansibility of Gases.** — This property which gases possess, of tending to occupy a large volume, is known as *expansibility* and is illustrated by the following experiment. A bladder fitted with a stopcock and containing a little air (fig. 125) is placed under the receiver of an air pump[1]. The receiver is at first full of air except for the space taken up by the bladder, and no change takes place in the latter because the conditions inside the receiver are the same as outside of it. Now let the air be exhausted from the receiver by means of the air pump. The effect of taking the air out of the receiver is to reduce the pressure on the outside of the bladder, which accordingly becomes larger, owing to the pressure of the particles of air inside of it. This, then, clearly shows the tendency of gases to occupy a greater volume. In connection with this experiment it should be noticed that the air inside the bladder presses equally in all directions.

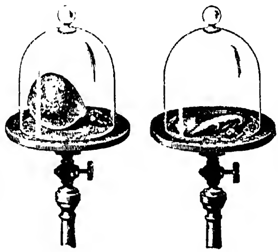


Fig 125.—Expansibility of Gases

When air is admitted into the receiver the bladder

[1] *Air pump*, an instrument for exhausting or pumping air out of a vessel. The *Receiver* is the "bell-jar" or glass cover seen over the bladder in figure.

collapses to its former size, the conditions being now the same as at first.

179. **Compressibility of Gases.**—When a gas expands and fills a larger space, as in the experiment with the bladder, the distance between the particles increases; when the volume of the gas is decreased, the particles are pressed closer together.

Now, by applying pressure we can force a body of gas to occupy a very small volume; and this property is known as the *compressibility of gases.* Liquids are also compressible, but to a much smaller extent than gases; and for general purposes they are taken as being incompressible. We know that it is impossible to force a quart of water into a pint measure, on the other hand, to compress a large volume of air or any gas into a small volume is quite easy.

If we push an empty tumbler, mouth down, into a pail of water, the air imprisoned in the tumbler is forced into a smaller space, and the farther we press down the tumbler the smaller the volume of the air becomes. Our having to press down the tumbler shows that the air is resisting compression, and if we cease pressing, at the same time keeping the tumbler perpendicular, the latter rises upwards, the air pushing the water out of it and regaining its former volume.

Changes in the Volume of a Gas due to Variations of Pressure.—So, in connection with our experiments on gases, besides noticing that a gas has neither definite size nor shape, we see (1) that the smaller is the pressure on a gas the greater is the volume of a gas (shown in the experiment with the bladder); (2) that the greater is the pressure on the gas the smaller is the volume (shown in the experiment with the tumbler); (3) that when the original pressure is resumed the gas returns to its first volume.

The volume of a gas, then, varies with the pressure to which it is subjected, diminishing as the pressure increases and increasing as the pressure is reduced. We shall see in the chapter on Atmospheric Pressure that it is important to know this in connection with the issue of gases from wastes into the mine workings.

It is known exactly how much air or any gas contracts or expands by a given variation of the pressure upon it, this having been discovered nearly two hundred and fifty years ago by a great scientist named Robert Boyle

Fluids.—Gases and liquids are termed *fluids*, because their particles, on the slightest pressure, move and change their relative position. Thus fluids are of two kinds, liquids and gases.

180. **The Force of Cohesion.**—Now, in nature there are certain great forces; and one of these is the force which holds the particles of a body together. This force is termed *cohesion*, and is greatest in solids, varying with the nature of the body. It exists less strongly in liquids, being just sufficient to keep the particles together; and it is not present at all in gases, the particles of a gas, as has been shown, repelling each other.

Existence of the Same Substance in Different States.—Heat acts in opposition to the force of cohesion, and many solids are known which, when their temperature is sufficiently raised, are converted into liquids, and the liquids, on further heating, into gases. Hence it is thought all bodies might be capable of existing in any one of the three states.

It is the same kind of matter, for example, which is found in the solid state as *ice*, in the liquid state as *water*, and in the gaseous state as *steam*. If we apply heat to a piece of ice, it melts into water; if we continue to heat the water, it boils and disappears in the form of

steam or water vapour. If we do not allow the steam to escape, but cool it down as it is formed, we again get water (this is termed *condensing* the steam); and, on continuing to abstract heat from the water, ice is the result. Mercury, again, the substance generally used in thermometers and barometers, while usually a liquid, freezes at a low temperature, and becomes a vapour at a high temperature. Oxygen and other gases have been converted into liquids by subjecting them to great pressure and low temperature; air, also, has been liquefied.

The Terms "Vapour" and "Gas".—The term "vapour", used in the preceding paragraph in connection with steam and mercury, means a gas formed from a body which is usually in the form of a liquid or solid, the term "gas" being generally applied to bodies such as oxygen, hydrogen, &c., which remain in the gaseous state under ordinary temperatures and pressures.

181. **General Effects of Heat.**—With a few exceptions, all bodies expand when heated and contract when cooled (§ 18). Each solid and liquid has its own rate of expansion or contraction, but air and all gases expand equally when equally heated and contract equally when equally cooled. Gases expand more than liquids, and liquids more than solids. When a gas is confined so that it cannot expand, and is then heated, its pressure is greatly increased, and may be so great as to burst the vessel in which it is contained. Hence boilers are fitted with *safety valves* to allow the steam to escape when the pressure reaches a certain amount. The increased pressure of the gas is believed to be due to the heat causing the molecules to move more rapidly. If free to do so, the molecules, we know, would fly apart (§ 177).

In building iron bridges, laying the rails of a surface railway, &c., precautions have to be taken against expansion, while in certain operations, as fixing or *shrink-*

ing iron tires on wheels, bracing up buildings by iron rods, advantage is taken of the properties of expansion and contraction. Air which has been warmed becomes lighter or less dense, and rises upwards, its place being taken by colder or denser air. In this way we get ventilation.

The ordinary form of *thermometer*, or instrument for measuring temperature, consists of a short glass tube having a very fine bore, and terminating at the lower end in a bulb. The top is hermetically sealed. Bulb and part of the stem are filled with mercury, and this rises farther up the stem or falls, according as it expands on being made warmer or contracts on being cooled. By means of a scale marked on the tube or affixed to it we are enabled to read the temperature of the body with which the thermometer has been in contact long enough to have ceased either to receive or lose heat.

The *temperature* of a body must be distinguished from the *quantity of heat* in the body. If we take a cupful of hot water out of a pailful, the temperature of the water in both vessels is the same, but evidently there must be a greater quantity of heat in the pailful than in the cupful. We may have a body at a very high temperature, yet possessing a small amount of heat, and conversely, a substance may be at a low temperature, and yet have a large amount of heat. Temperature, then, indicates the *intensity* of the heat of the body, or how hot or cold the substance is. On the other hand, the quantity of heat in a body depends on the weight of the body, its temperature, and the kind of material of which it is composed.

In *graduating* the thermometer two fixed points are chosen. These are the points at which, under the ordinary atmospheric pressure (chap. xxxiii), the top of the

thread of mercury stands when the thermometer is placed first in melting ice (called the *freezing-point*), and then in steam from boiling water (called the *boiling-point*). The space between the two points is divided into equal parts termed *degrees* (written °). In the *Fahrenheit* scale (Fah. or F.) the freezing-point is called 32°, and there are 180 equal divisions or degrees. Therefore the boiling-point is 212°; that is, 32 + 180. In the *Centrigrade* scale (C.) the freezing-point is called 0°, and, since the distance between the two points is divided into 100 equal spaces, the boiling-point is consequently 100°. In a third scale, called the *Réaumur* (R.), the freezing-point is 0° and the boiling-point 80°, the number of divisions being 80. As the distance between the freezing-point and boiling-point is the same on each scale, it will be seen that the degrees or spaces on the R. scale are nine-fourths and those on the C. scale nine-fifths as long as those on the F. scale.

Boiling-points.—It should be observed that the temperature at which water boils is not always 212° F. (or 100° C.); but depends on the pressure on the water. If this is greater than that of the atmosphere at sea level, then the temperature at which the water boils is higher than 212° F.; if less, then the boiling-point is lower than 212° F. Also different liquids have each their own boiling- and freezing-points, but the same liquid always boils at the same temperature for any given pressure.

182. **Transmission of Heat.**—By this is meant the transference of heat from one point to another. This may take place in three different ways, namely, by *conduction*, *radiation*, and *convection*.

Conduction.—If we put one end of a knitting needle or wire into a fire, we find the other end soon becomes hot. The heat passes, or is "conducted", along the wire from molecule to molecule, and we call the wire a *con-*

ductor of heat. Metals are good conductors of heat, but many other substances are bad conductors. Thus, if we substitute a piece of wood for the wire, it catches fire, and we can hold it until it has almost all burnt away. Wood, then, is a bad conductor of heat

In *radiation*, heat passes from one body to another in rays through space. Thus it is by radiation that a person standing in front of a fire is warmed, and by which the heat of the sun reaches us. The temperature of the air, or medium through which the heat rays pass, is not affected.

Convection is the carrying of heat by the motion of the heated particles from one point to another. It takes place in liquids and gases. If a little bran or sawdust be put into water in a glass flask, and the latter heated over a spirit lamp or Bunsen burner, the direction of the *convection currents* can be seen. The water near the source of heat expands and ascends, the colder and heavier particles at the sides sinking down. In this way the mass of the liquid is gradually raised in temperature. Heat passes by *radiation* to a kettle suspended over a fire, is *conducted* through the bottom, while the water inside is made hot by *convection.*

183. **Nature of Heat—The Steam Engine.**—Heat is a *form of energy*, and energy is "the power of doing work". Thus the steam in a boiler possesses energy or power of doing work, because of the heat imparted to the water in the production of the steam and also to the latter itself; and a steam engine may be described as a machine for transforming into mechanical work the heat energy obtained by the combustion of the fuel in the boiler furnace.

Inside the *cylinder* is the *piston*, and connected to this is the *piston rod*, which projects from the front of the cylinder (fig. 179). A steam pipe passes from the

boilers to the cylinder, and the steam entering the latter drives the piston from one end of the cylinder to the other, thereby working a pump or revolving a drum which may be connected to the outer end of the piston rod. After driving the piston from one end of the cylinder to the other the steam escapes and fresh steam at the same time enters the cylinder at the other side of the piston and forces the latter back into its first position.

184. **Use of Compressed Air in Mines.**—It has been mentioned several times that compressed air is used underground to work machines, such as drills, coal-cutters, &c. Our experiment with the tumbler enables us to understand the procedure. The air is drawn from the atmosphere into a cylinder, termed the *air-cylinder*, and is there compressed by a steam engine, its pressure being thus increased. From the air-cylinder the air passes into the *air-receiver*, and from the air-receiver is conveyed into the mine in pipes. Here it works the machine required by expanding to its former volume, thus giving out its increased pressure.

CHAPTER XXVII

SOME CHEMISTRY AND PHYSICS—(*Continued*)

Properties of Matter—Special and General Properties—Weight—Indestructibility of Matter

185. **Properties of Matter.**—All kinds of matter possess what are known as *properties*. By "properties" here are simply meant *qualities*, such as colour, taste, smell, hardness, &c., which we recognize in the substance by means of our senses. Thus sweetness is a property of

sugar, hardness of iron, and so on. It is by its properties, then, that one substance is distinguished from another.

Now, such properties as sweetness, hardness, &c., which are possessed only by some kinds of matter, are called *special properties*, while properties such as weight, indestructibility, &c., which belong to *all* kinds of matter, receive the name *general properties.* In the present chapter we are concerned with the general properties of matter only, and the two of which we need take any notice are the ones mentioned, namely, *weight* and *indestructibility*.

186. **Weight.**—All matter possesses weight. A cubic foot of platinum, one of the heaviest of the known metals, weighs about 1342 lb. (nearly twice as much as a cubic foot of lead), a cubic foot of water about $62\frac{1}{2}$ lb., a cubic foot of air under ordinary conditions about $1\frac{1}{4}$ oz., and a cubic foot of the gas hydrogen, the lightest substance known, about $39\frac{1}{2}$ grains, or nearly $\frac{1}{10}$ oz.

Every person is aware that solids and liquids have weight, because to support or raise them requires the exertion of force, and we say they are "heavy" or "light", according as we think they possess much or little weight. That gases have weight, however, does not always appear certain. Thus a balloon filled with hydrogen rises in the air instead of remaining on or falling to the ground, as bodies having weight usually do. Yet we see from the preceding paragraph that hydrogen does possess weight, and the balloon ascends simply because hydrogen is lighter, volume for volume, than air, just as a cork, which everyone knows to possess weight, rises when placed at the bottom of a vessel of water, the cork being lighter, bulk for bulk, than the water.

To weigh air or any gas we use a large glass flask, fitted with a tap or stopcock (fig. 126). The air is exhausted from the flask by means of an air pump, the stopcock closed to prevent more air from entering, and the flask, thus quite free of air, weighed. The stopcock is now opened, the air rushing into the flask, which, now full of air, is again weighed. The second weight is greater than the first, and the increase is, of course, the weight of the air that has entered the flask. If the volume of the flask were, say, a cubic foot, then the difference of the weights when the flask is full of air and when empty would be the weight of 1 c. ft. of air. This is how Otto von Guericke of Magdeburg (the inventor of the air pump) weighed air in the seventeenth century; up till then air was believed to be without weight.

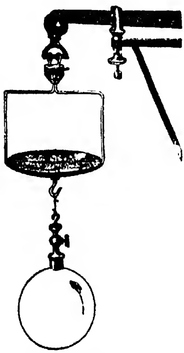


Fig 126 —Weight of Air

By weighing other gases it can be ascertained whether they are lighter or heavier than air. Thus hydrogen is about 14½ times lighter, nitrogen a little lighter, and oxygen a little heavier than air. As is evident from §§ 179, 181 any given volume of gas (a cubic foot, for example) will weigh more when the pressure upon it is great than when it is small; and less when the temperature is high than when it is low; hence, when ascertaining the weights of any two gases for the purpose of comparing the one with the other, the pressures and the temperatures, as well as the volumes, must be the same.

187. **The Weights of the Mine Gases Compared with the Weight of Air.**—Four gases, called respectively *marsh*

gas (firedamp), *carbonic oxide* (whitedamp), *sulphuretted hydrogen* (stinkdamp), and *carbonic acid* (chokedamp), are likely to be found in coal mines (chaps. xxxi–xxxii); and it is very important that we should have some idea of their weights compared with the weight of air. If, then, we were to weigh equal volumes of air and each of the mine gases, at same temperature and pressure, and call the weight of the air 1, the weights of the other gases would be as shown below:—

Weight of Volume of Air (called 1).	Weight of Equal Volume of Gas (at same temperature and pressure).
1	0·56 marsh gas.
1 . .	0·97 carbonic oxide.
1 .	1·18 sulphuretted hydrogen.
1	1·53 carbonic acid gas.

Thus marsh gas is about half the weight of air, whitedamp a little lighter, and stinkdamp heavier than air, carbonic acid gas, the heaviest, being about 1½ times as heavy as air.

These numbers, 0·56, 0·97, 1·18, and 1·53, are termed the *specific gravities* of the gases, the specific gravity of a gas being its weight compared with that of an equal volume of air, under the same conditions of temperature and pressure, the weight of the air being called 1. Sometimes the term *density* is used instead of specific gravity, but generally density is taken to mean the weight of the gas compared with the weight of an equal volume of hydrogen.

188. **What Weight Is.**—It will be well to enquire what weight is. It has been explained (§ 180) that there are different forces in nature, *cohesion* being one of such forces. Another, termed *gravity*, is the force with which the earth is continually drawing, or tending to draw, all bodies towards its centre. Now what we call the "weight" of a body is simply the force with which

gravity is acting on the body, or, in other words, the force with which the body is attracted to the earth. Thus, for example, if we throw a ball up into the air it soon comes down again. We say this is because of its "weight", weight here really meaning the downward force with which the earth draws the ball towards its centre. If the ground is sloping, the ball will run to the lowest point, and if it rolled into a pit it would fall to the bottom. Ordinarily, of course, when speaking of weight we never think of the force of gravity, regarding the weight of a body as just the amount the body weighs.

It is important to observe that the force of gravity is always acting, hence a body always has weight. Thus if we place an object on a table, the table must be able to support the weight of the object (or, in other words, resist the force of the earth's attraction), or the object will fall to the floor. Then the floor has to be strong enough to support the weight of both table and object or they will drop down to a lower level. In chap. xxxvii it will be seen how the force of gravity is utilized in the transport of hutches in the mine.

189. We come now to the **Indestructibility of Matter.** The accepted theory is that matter can neither be created nor destroyed. When this statement is first made to us we have a difficulty in understanding how it can be true. That is because we are accustomed to seeing things disappear *as such*, as, for instance, coal placed on a burning fire. But we must note that though a body ceases to exist as such there is *no loss of matter*, but simply a change of state. Hence in the case of coal, although the coal itself vanishes when burnt, there result other substances, namely smoke, colourless gases, and water vapour, which ascend the chimney; and ash, which remains behind.

Now if coal could be burnt in such a way as to render

it possible to collect the gases, &c., produced, or the *products of combustion*, as the resulting substances are termed, we should find that they would actually weigh *more* than the coal itself. This is owing to the fact that coal when burning takes up oxygen from the air—air, as already mentioned, consisting mainly of two gases, oxygen and nitrogen. The products of combustion of the coal will, then, be heavier than the coal by an amount equal to the weight of oxygen taken out of the air.

The same thing happens in the case of a burning candle (or taper), and we can use this in an experiment instead of coal. First, however, we must satisfy ourselves that the burning of the candle does result in the production of other substances.

The candle is composed of carbon and hydrogen, and if we hold a small porcelain dish filled with cold water in the flame we find that soot and moisture gather on the outside of the dish. The soot is carbon in a finely divided state, and the water is due to the hydrogen of the candle and the oxygen of the air, as will be explained in the next chapter. The water is given off in the form of vapour. The cold surface of the dish condenses the vapour into water.

But some of the gas about which we learnt in §187, namely, carbonic acid gas, is also given off. This is due to the carbon of the candle and the oxygen of the air, as likewise will be explained in the next chapter. The presence of this gas is shown by the fact that it makes lime water turbid. To prove that it is given off by the burning of the candle we first pour a little clear lime water into a glass jar, or colourless glass bottle with a narrow neck, then shake the jar. The lime water remains clear, showing that there is no carbonic acid gas present. We now, by means of a special spoon or piece

of wire, lower the lighted candle into the jar. The flame soon goes out, and if we shake the jar the lime water becomes milky, indicating that carbonic acid gas has been produced by the burning of the candle.

Having now seen that the combustion of the candle does result in the formation of other substances, the next step is to ascertain whether these substances do weigh more than the candle. For the purpose of collecting

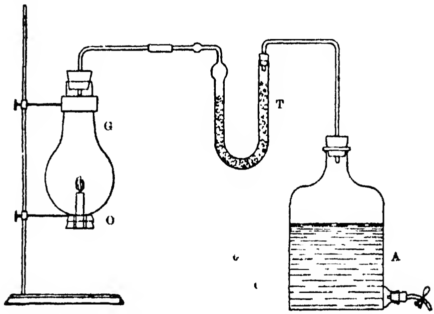


Fig. 127 - Candle Experiment for showing Indestructibility of Matter

the products of combustion we may use the apparatus shown in fig. 127. G is a wide glass flask fitted with a cork at each end. The cork at O, the lower end, has a hole for the candle and small holes for the admission of air. T is a U-tube filled with pieces of a substance called *caustic soda*, which absorbs the water and carbonic acid gas produced by the burning of the candle, and A a glass vessel or can filled with water. The U-tube is connected to G and A by small bent glass tubes as shown. The water running out of A draws the air up through the holes in O.

We now proceed to find out whether there is a gain

ir weight. It will be seen that there is no need to wait until the whole candle has been consumed. Before lighting the candle the apparatus, with the exception of A and the supporting stand at the left, is weighed. Then, A having been connected up and the stopcock opened, the cork O is removed, the candle lighted, and O quickly replaced. After allowing the candle to burn for a time the flow of water is stopped and the candle goes out. The apparatus is now weighed as before, and found to be heavier, the increase being due to the oxygen which has been taken from the air.

This experiment, then, may be taken as showing the truth of the statements made as to the indestructibility of matter, and other experiments which are being performed daily all go to show that matter, though it may change its state, can neither be created nor destroyed.

In the experiment just described the wide flask (or a tube or lamp chimney) may be used alone, the caustic soda being kept in the upper part by means of a coarse piece of gauze placed in the flask. The tube is suspended from the end of a balance beam and counterpoised. Then the candle is lighted and the apparatus is seen to increase in weight.

CHAPTER XXVIII

SOME CHEMISTRY AND PHYSICS—(*Continued*)

Physical and Chemical Changes—Elements and Compounds—Chemical Action—Mechanical Mixtures

190. **Chemistry and Physics.**—We are now in a position to understand what chemistry and physics treat of (chap. xxvi). We have seen that matter is capable of

undergoing changes. Now chemistry and physics are the sciences that deal with the changes which take place in matter—chemistry with changes (termed *chemical changes*) affecting the composition of matter, and physics with all other changes, as, for example, change of position, change of volume, &c. (called *physical changes*).

191. **Physical and Chemical Changes.**—It is very important that we should have a clear understanding of what is meant by chemical changes, and the following will make the matter plain.

If we move a piece of iron from one place to another, or throw it up in the air, or heat it, these are all physical changes. If we magnetize the piece of iron, whereby we impart to it the power of attracting other pieces of iron, that also is a physical change. Again, if we break a match, that likewise is a physical change. In all these changes nothing has been done to affect the composition of the substances. At the end the piece of iron still remains iron, and the broken match is otherwise the same as before. The iron being made hot does not affect its composition, as neither does magnetizing it. It soon grows cold again, and also soon loses its magnetism, and the properties imparted to it through being made hot or converted into a magnet are then lost. Converting ice into water and water into steam, and vice versa, are also physical changes, ice, water, and steam consisting of the same kind of matter (§ 180).

If now we ignite the match which was previously broken, we have a chemical change. Here the composition of the substance is affected, the burning or combustion of the match being accompanied by the production of new substances with properties different from those of the match, just as has been seen to be the case when a candle is burnt. The burning of a candle

and of coal are, then, also examples of chemical change. A further example is the ignition of a little gunpowder. The gunpowder disappears with a flash, being converted into smoke and gases, and, no matter how long we wait, the substances thus formed do not return again to their former state. A chemical change is, then, permanent; also it must be carefully observed that when a chemical change takes place at least one new substance is formed, having its own particular properties. More will be seen as to this in the present chapter.

192. **Chemical Elements and Chemical Compounds.**—Now as the result of the efforts of chemists in enquiring into the composition of matter it is found that all known substances can be divided into two great classes, termed respectively *elements* and *compounds*. To impress this fact on our minds we may state it in the following way:—

Substances

Elements — Not elements (*i.e.* compounds).

That is, all substances are either elements or not elements; if they are not elements, then they must be compounds.

Elements.—Now an element is a substance which contains only one kind of matter. Treat any element, then, as we may we can never get but one kind of matter from it. Thus oxygen is an element, and from oxygen only the kind of matter known as oxygen can be obtained. Again, from hydrogen, which is also an element, we can get only the kind of matter known as hydrogen. Similarly with all other elements, each consisting of only one kind of matter. Other names used instead of element are *simple substance, elementary substance,* and

original substance. Or instead of substance the term body is used, thus *simple body*, &c.

Altogether there are about seventy known elements. The following list contains the names of the most important:—

Chlorine } *gases*	Lead
Hydrogen } *gases*	Magnesium
Oxygen } *gases*	Phosphorus
Nitrogen } *gases*	Platinum
Mercury (*liquid*)	Potassium
Aluminium	Silicon
Calcium	Silver
Carbon	Sodium
Copper	Sulphur
Gold	Tin
Iron	Zinc

With the exception of the five indicated, all mentioned in the list are solids.

193. **Compounds.**—Elements go together to form compounds, hence a compound, unlike an element, consists of two or more different substances. By treating the compound in a certain way we can obtain from it the different substances of which it is composed. Thus if we heat in a tube (T, fig. 128) a little of the red powder called oxide of mercury, which is a compound of oxygen and mercury, the mercuric oxide (compounds of oxygen and another element are termed *oxides*) is "decomposed" or "split up" into these two substances.

In performing this experiment the mercuric oxide is put into the tube T, and the mouth of the latter closed by a tightly fitting cork, through which the end of a suitably bent glass tube, called a *delivery tube*, has been previously passed. The other end of the delivery tube is guided into a trough, W, called a *pneumatic trough*, and the tube T fixed to a stand. Over the end of the delivery pipe in the trough a *beehive shelf* is placed (this

has a hole in the top) and water poured into the trough until it covers the beehive shelf. An inverted tube, T′, filled with water, is now placed over the hole in the beehive shelf. To prevent the water from running out of the tube T′ while being inverted the mouth is kept covered until it is below the level of the water in the trough.

On applying heat to T the mercuric oxide, as has been

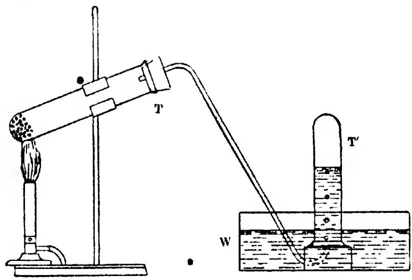


Fig 128 —Decomposition of Oxide of Mercury

said, is decomposed. The oxygen passes down the delivery tube and bubbles up through the water contained in T′, forcing out or displacing the water. The tube T′ thus becomes filled with oxygen, and is then removed from the trough. Oxygen has no colour (therefore it cannot be seen), no taste, and no smell, and in testing for its presence a glowing splinter of wood is introduced into the tube. The oxygen causes the splinter of wood to burst into flame; the reason of this will be explained in the present chapter. The mercury is deposited in globules on the cooler parts of T.

Very often the tube T alone is used in this experiment, the glowing chip of wood being introduced into it after

the heat has been applied for a sufficiently long interval. We may continue the heating until the whole or part only of the oxide in the tube disappears; but since there is never any loss of matter the weights of mercury and oxygen produced will always equal the weight of oxide used. It will be observed that the decomposition of the mercuric oxide is a chemical change.

Other chemical compounds are water, sugar, and salt. Water is composed of hydrogen and oxygen, and if we split it up by passing a current of electricity through it we obtain these substances from it. Sugar is a compound of carbon, hydrogen, and oxgen, and salt of sodium, and chlorine. Again, the greater number of minerals are chemical compounds, quartz, for example, consisting of silicon and oxygen

In all these examples it will be observed the compound possesses properties entirely different from those of the elements forming it. But this is not to be wondered at, because when elements unite to form compounds a chemical change takes place, and the result of that, we have already learnt, is the formation of at least one new substance which has, of course, its own particular properties. There are thousands of chemical compounds, and though there are only about seventy elements, if we recollect that the words comprising the English language are all built up out of twenty-six letters, we can understand how it is possible for so many different substances to be formed out of so few. One letter going with different letters, or with the same letters arranged in a different order, forms different words, and similarly one element uniting with different elements, or the same elements in different proportions, forms different compounds. Thus oxygen uniting with mercury forms mercuric oxide, with hydrogen water, with hydrogen and carbon sugar, and

with silicon quartz. Again, the mine gases carbon dioxide and carbon monoxide (whitedamp) are chemical compounds of carbon and oxygen, each containing the same amount of carbon, but carbon dioxide having twice as much oxygen as carbon monoxide. Oxygen combines with all the elements except two to form compounds.

194. **Chemical Action.**—Elements unite to form compounds through the power of a great force of nature termed *chemical attraction* or *affinity*. The molecules of the elements require to be brought into contact, and when that has been done and any further means—such as heating—necessary to cause the chemical force to act adopted, the result is the formation of the new substance. Chemists describe this by saying that *chemical action* takes place between the elements, or that they "act chemically" on one another. They also say that the elements "combine chemically" or "unite chemically", or that they enter into "chemical combination" or "chemical union". Chemical action takes place also when compounds are decomposed into their constituent elements, this being implied by the terms "decomposing", splitting up", &c. When a compound is decomposed the force holding the elements together (that is *chemical affinity*) has to be overcome.

195. **Mechanical Mixtures.**—It is necessary to carefully distinguish between chemical compounds and *mechanical mixtures*. A mechanical mixture consists of two or more substances simply mixed together, as sand and sugar, salt and sugar, &c. No chemical action takes place between the substances, and they can, therefore, be separated again by purely physical means. Thus if we mix iron filings and sulphur we can remove the iron filings by means of a magnet, leaving the sulphur behind, or the sulphur could be washed away with

water, leaving the iron filings behind. If, however, the mixture is heated in a test tube, the sulphur is observed to melt, then the contents of the tube to glow brightly, and if the tube is broken after it has cooled, and the resulting metallic-looking mass powdered, nothing is to be seen of the sulphur or filings, and the magnet is found to have no effect on the particles. What has happened is that the sulphur and iron have ceased to exist as such, and now form a chemical compound of sulphur and iron. Before the heating we had particles of sulphur existing side by side with particles of iron (a mechanical mixture of sulphur and iron filings). As the result of the heating, chemical action took place; the iron and sulphur united, and an entirely new substance was formed, showing no trace of either the iron or sulphur.

It is very important to observe that the properties of a mechanical mixture are the mean of those of the substances forming it, not distinct from them, as in the case of a compound. Thus sulphur is yellow and iron grey in colour. When we mix the two substances together the colour is yellowish-grey, that is, a colour neither yellow nor grey, but between the two. In a mechanical mixture the substances may be present in any proportion; on the other hand, when elements *combine* they do so in *definite proportions*.

Air, it should be noted, is a mechanical mixture of gases, while the gases met with in coal mines are chemical compounds. Gunpowder is a mechanical mixture of three substances, sulphur, charcoal, and saltpetre.

196. **Combustion.**—When substances unite chemically, heat is usually given off. This was evident in the experiment with the sulphur and iron, and it can also be shown by pouring cold water on to *quicklime* (fig. 129). The lime and water both become hot, steam being

formed. These results are due to the chemical combination of the quicklime and water. The white powder produced is called *slaked lime.*

Now when chemical union goes on so quickly that light as well as heat is produced we say *combustion* is taking place. The only case of combustion with which we are concerned is that in which substances are burnt in air. Coal, wood, &c., contain carbon and hydrogen, and air oxygen, and when the coal (or wood, &c.) is burnt the carbon and hydrogen unite chemically with the oxygen of the air—the carbon and oxygen to form carbonic acid gas, and the hydrogen and oxygen to form water. We see, then, that the combustion or burning of coal, a candle, &c., are instances of chemical combination, and we can now understand how the moisture came to appear on the outside of the porcelain dish, as seen in the experiment in the preceding chapter, and also how the carbonic acid gas came to be present in the jar after the candle had been allowed to burn in the latter—they were the result of the chemical union of the hydrogen and carbon with the oxygen of the air.

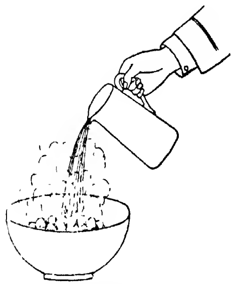


Fig 120.—Water Poured upon Quicklime

The substance which burns is called the *combustible,* and the substance in which it burns, or which surrounds it, is termed the *supporter of combustion.* Thus coal, wood, &c., are combustibles, and, of course, the oxygen is the supporter of combustion. It is really air that surrounds the combustible, but it will be clearly shown

in the next chapter that it is the oxygen in the air that supports combustion.

When a substance will not burn in air we say it is *incombustible* or *non-combustible*, and we also say that any gas in which a light will not burn is a *non-supporter of combustion.* Thus, as will also be shown in the next chapter, hydrogen gas burns in air, but if we introduce a light into the hydrogen the light is extinguished. We say then that hydrogen is combustible, but does not support combustion. Nitrogen, again, will not burn in air, and extinguishes lights put into it. Hence we say nitrogen is incombustible and a non-supporter of combustion.

It will be seen later on that all the mine gases, with the exception of carbonic acid, are combustible, and that none of them support combustion, air (that is the oxygen of it) being the only supporter of combustion in the ordinary sense of the term.

CHAPTER XXIX

SOME CHEMISTRY AND PHYSICS—(*Continued*)

The Elements Carbon, Sulphur, Nitrogen, Oxygen, and Hydrogen.

Five elements about which we require to know something are *carbon*, *sulphur*, *nitrogen*, *oxygen*, and *hydrogen.*

197. **Carbon and Sulphur.**—Carbon and sulphur are solids. A diamond is pure carbon, as also are charcoal and graphite. The last-mentioned is the substance used in the manufacture of so-called "lead" pencils. Carbon we know is the chief constituent of

coal, and goes to the formation of many other substances.

Sulphur, like carbon, is a combustible substance, burning in air or oxygen with a bluish flame. When heated to a certain temperature it is converted into a vapour (§ 180). Sulphur, we have seen, is one of the ingredients of gunpowder, and chemically combined with hydrogen it forms the gas sulphuretted hydrogen (the stinkdamp of mines).

198. **Nitrogen and Oxygen—Air.**—Nitrogen and oxygen are invisible gases without taste or smell. It has already been mentioned that air is a mechanical mixture, consisting mainly of these two gases. Out of every 5 c. ft. of air about 4 c. ft. are nitrogen and 1 c. ft. oxygen. But although oxygen thus forms by volume only about one-fifth of air it is this gas which is the life-giving element and the great supporter of combustion. The nitrogen dilutes the oxygen and renders it fit for breathing. To breathe pure oxygen for any length of time would be very injurious, also substances which burn slowly in air would be quickly consumed in pure oxygen; and some substances which will not burn in air do so readily in oxygen. Thus iron wire can be made to burn in oxygen.

It is quite evident that every person and animal must have air if they are to live, and to show that substances when burning need air an ordinary bottle with the bottom cracked off may be placed over a lighted candle, care being taken to prevent air from entering the bottle at the foot. The flame soon dies out. If, however, the bottle be supported on two books, so that air is allowed to enter at the bottom, the candle continues to burn.

Preparation, &c., of Nitrogen.—Now let some nitrogen be prepared. From a stick of phosphorus a small piece is cut off, dried quickly with blotting paper,

and placed in a small saucer which is floated in a basin of water (phosphorus is a very inflammable substance, and has to be kept and cut under water; it must not be touched with the fingers). A bell-jar is placed over the saucer (fig. 130), the stopper removed, and the phosphorus ignited by touching it with a hot wire. The wire is immediately withdrawn and the stopper replaced. Dense white fumes are seen to form in the jar as the phosphorus burns. These are due to the chemical combination of the phosphorus with the oxygen of the air, the whole of the oxygen inside the jar being consumed as the phosphorus continues to burn. After a short time the white fumes disappear, being dissolved in the water, and nothing is left in the jar but nitrogen. It will be observed that the water stands at a higher level in the jar than outside, having risen to take the place of the oxygen. The stopper is removed, and a burning taper is inserted into the jar. The taper is at once extinguished, showing that nitrogen is not a supporter of combustion; also the nitrogen does not burn, proving that it is not combustible.

Fig. 130.—Oxygen removed from Air in Bell-jar by means of Phosphorus

Oxygen.—It was seen in the experiment with the mercuric oxide that oxygen supports combustion and is incombustible. When it is desired to obtain this gas in any quantity (for experimental purposes) a substance called *potassium chlorate* is used. This is a compound of potassium, chlorine, and oxygen. When heated, it is decomposed and the oxygen set free. Usually another substance having the name *manganese dioxide* is mixed with the potassium chlorate. The apparatus employed is identical with that shown in fig. 128, except that a

glass flask is used for the tube T, and glass cylinders (C, fig. 134) instead of T′. Heat is applied to the flask, and the gas collected as with the tube T′. As each cylinder is filled the mouth is covered with a glass disc. A piece of charcoal is ignited, and the greater brightness with which it burns in oxygen compared to air observed. Similar experiments are made with sulphur and phosphorus.

As already stated, iron wire will burn in oxygen. One end of the wire is coated with sulphur, which is then ignited. This end is put into the oxygen, and the wire being heated up by the sulphur burns rapidly and with great brilliance, throwing off sparks. Instead of wire a piece of steel watchspring may be used.

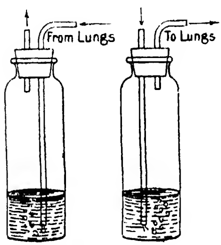
199 **Oxidation.**—The special name given to compounds of oxygen with other elements has already been mentioned (§ 193), as also the readiness of this gas to enter into chemical combination. With some bodies it combines at the ordinary temperature, and in this way we get iron rust, rust being a chemical compound of iron and the oxygen of the air, formed in the presence of moisture. The chemical name for rust is "oxide of iron". The process of chemical union with oxygen is called *oxidation*, and the rusting of iron is an example of oxidation proceeding slowly. Combustion, it will be understood, is merely rapid oxidation.

200. **Other Constituents of Air.**—Other elementary gases present in air in small proportions are the recently discovered argon, helium, &c.; but disregarding these, mixed with the oxygen and nitrogen are small amounts of carbonic acid gas and water vapour, and also various impurities.

Carbonic Acid Gas in Air.—The proportion of carbonic acid gas in the air varies at different places. In the open country the air contains from 3 to 4 volumes in

10,000, but the amount is much greater in towns and badly ventilated places. This is because people give off this gas in breathing. and also because it is, as we know, produced by the burning of fires, &c.

The carbonic acid gas given off in respiration is due to the oxidation of carbon in our blood, the oxygen drawn into our lungs entering the blood and there combining with the carbon. To show that we do breathe out this gas the air from our lungs may be blown through a little clear lime water (using a straw or tube, or a bottle fitted up as illustrated in fig. 131), the lime water becoming "milky" when shaken, while to satisfy ourselves that the gas is actually produced within our bodies a little clear lime water is shaken up in ordinary air or put into a bottle (fig. 132) and the air inhaled through this. In either case the lime water remains clear, the amount of carbonic acid gas ordinarily present in the air being too little to affect it unless the lime water is allowed to stand for a time.



Figs 131, 132.—Experiment to show Difference between Inspired and Expired Air

Water Vapour in Air.—Air always contains water vapour (§ 21). In addition to the amount evaporated from the surface of the land and from the sea, &c., vapour, as has been shown, results from the burning of coal, &c., and it is given off in breathing.

The amount of water vapour the air can contain depends on its temperature. The higher the temperature of the air the more vapour it can take up. It is for this reason that the air in deep mines is *drier* than

in shallow mines. Air which has its temperature raised is able to absorb more moisture, and it is this power of absorbing moisture to which the name dryness is given. The temperature of the earth's interior increasing with the depth (chap. iii), deep mines are at a higher temperature than shallow mines and also (except perhaps on a hot summer's day) than the air on the surface. The air entering the deep mine from the surface is heated up by the strata, and consequently made drier.

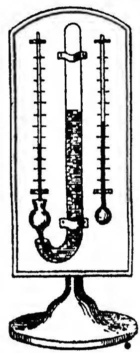


Fig. 133.—Dry- and Wet-bulb Hygrometer

When air can contain no more water vapour at any given temperature it is said to be *saturated.* If the temperature is then raised the air is able to take up more moisture, until it is again saturated. If the temperature is once more increased there will be a new saturation point, and so on.

When air is saturated and the temperature then falls, the vapour contained in the air in excess of what is required to saturate it at the lower temperature will pass back into water or be *condensed.* This is the cause of moisture being sometimes deposited on the sides, &c., of roads in shallow mines, near the shaft bottom, during hot summer days. The warm air passes into the mine loaded with vapour, and is there chilled.

To show that air contains water vapour, it is only necessary to bring a tumbler of very cold water into a warm room in which are several persons. The cold outer surface of the tumbler becomes wet, owing to the cooling of the air in contact with it and consequent condensation of water vapour. Again, the cold surface of a mirror when breathed upon becomes dim or clouded with

moisture, showing that we do exhale water vapour. For ascertaining the degree of moisture, or *humidity*, in the air an instrument called a *hygrometer* (fig. 133) is used.

Carbonic acid gas and water vapour, like oxygen and nitrogen, are essential constituents of air.

Impurities in Air.—Carbonic acid gas, though necessary in air, is injurious when it exceeds a certain amount. It then becomes an impurity. More will be seen as to this gas in chap. xxxi. Besides carbonic acid gas, air contains, as impurities, dust particles, living germs, and traces of certain gases. The exact nature and amount of the impurities in the air of any district depend on the local conditions.

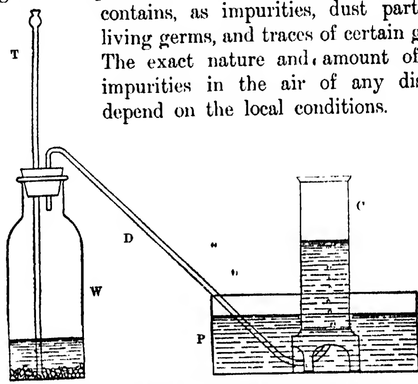


Fig. 134.—Apparatus for the Preparation of Hydrogen

W. Glass bottle; T, Thistle-funnel; D, delivery-tube; P, pneumatic trough; C, glass cylinder

201. **Hydrogen, Preparation.**—The apparatus used is shown in fig. 134. Some granulated zinc is put into the bottle W (or into a two-necked Woulfe's bottle), and sufficient water poured down the thistle-funnel to cover the zinc. A little dilute sulphuric acid is now added, and chemical action begins. The sulphuric acid is a compound of hydrogen, sulphur, and oxygen, and owing

to the chemical action the hydrogen is liberated, and passes along the delivery-tube. It is collected in the same way as oxygen. As it is explosive when mixed with air, all the air in the bottle must be allowed to escape before beginning to fill the first cylinder. In consequence of the lightness of this gas, the cylinders must be kept mouth down when filled. If the chemical action slackens, a little more sulphuric acid is poured down the thistle-funnel.

Experiments to illustrate Properties of Hydrogen.—(1) *Hydrogen is combustible, but does not support combustion.* A lighted taper is put into a cylinder of the gas (keeping the cylinder mouth downwards); the hydrogen catches fire and burns with a pale-blue flame, but the taper is extinguished on being pushed into the gas.

(2) *Lightness* (§ 186). A cylinder containing air only is held mouth down, and a cylinder of hydrogen emptied into it by pouring the gas *upwards*. On introducing a lighted taper into the upper cylinder there is an explosion, due to the mixture of hydrogen and air, showing that the gas has passed from the lower to the upper cylinder. A light put into the cylinder originally containing the hydrogen shows it to be quite free of the gas.

(3) *Hydrogen, when burning in air, forms water vapour, due to chemical union with the oxygen of the air.* A glass jet can be substituted for the delivery-tube and the gas ignited as it issues from the jet (first making sure that it is pure hydrogen, and not a mixture of hydrogen and air, that is being given off, in case of an explosion). Water is deposited on the cold surface of a tumbler held over the jet, due to the condensation of the vapour. By weight one-ninth of water is hydrogen and eight-ninths oxygen.

CHAPTER XXX

EXPLOSIVES AND BLASTING

Boring the Shot Holes—Charging and Firing—Miss- and Hang-fires—Electric Blasting—What an Explosive is and How it Acts—Composition of Explosives—Blown-out Shots—Permitted Explosives—Substitutes for Blasting.

We know that explosives are put into holes bored for them and are then fired, and we have already seen how they are used both at the bottom of a sinking pit and in breaking down the coal. It now falls for us to learn something of the boring and charging of the holes, and of the other matters mentioned in the heading. It is better, in the first instance, to acquire some knowledge of the various subjects in the order given; afterwards each, as for example "charging and firing", can be studied separately as fully as necessary.

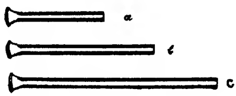


Fig 135.—Set of Hand-drills

202. **Boring the Shot Holes.**—Fig. 135 shows *hand-drills*, to which reference has already been made. They are steel rods, usually of octagonal section, with a cutting edge at one end and a face at the other, on to which blows from a hammer are delivered. The action is therefore percussive (§ 108), and to ensure the hole being circular the drill must receive a partial turn after each stroke of the hammer. The cutting edge is shaped to suit the nature of the rock The "short drill", *a*, is used first, then the "middle drill", *b*, and, lastly, *c*, the long drill". In what is known as *single-handed boring* one person does the work, holding the drill in one hand and delivering the blows with the other; in *double-handed*

boring one man holds and turns the drill, and one or two others strike the blows.

For boring holes in soft rock a tool called a *jumper* is sometimes used. This may be six or more feet long. It has a cutting edge at one end and an enlargement near the other. The hole is bored by moving the tool to and fro, giving it always a partial turn.

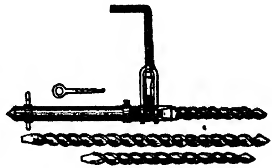


Fig 137 —Ordinary Ratchet Machine and Drills

The drill—twisted steel—is inserted into a socket at the end of a screw The screw works through a nut at the end of the barrel, and is rotated by a ratchet handle.

Hand-boring machines.—Reference has also been made (§§ 126, 148) to the use of *power machine drills*; for the general work of the mine *hand-boring machines* are employed, and fig. 137 shows the ordinary "ratchet" machine, with which most miners are familiar. The motion is rotary (§ 110). Fig. 138 illustrates another machine; in this the stand takes the place of the prop required with the machine shown in fig. 137.

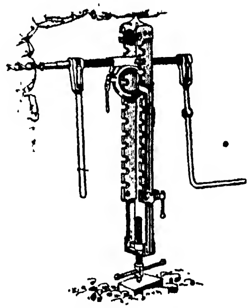


Fig. 138 —Elliot Boring Machine

As the boring proceeds, the hole has to be cleaned out, and this is done by means of the *scraper* or *cleaner* (fig. 139), a thin copper rod with a circular piece formed at one or both ends. The other tools shown in fig. 139 are used in charging the hole. It will be seen from

G. R. 12 (*d*), that tools made of iron or steel must not be employed. This is to ensure greater safety, but tools of any material are unsafe if not used with the utmost care. The stemmer, made of wood or copper, has a groove at one end, which fits the needle or safety fuse. The needle, of copper, has an "eye" at one end, and tapers to a point at the other.

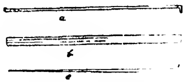


Fig. 139.—*a*, Scraper or Cleaner *b*, Stemmer or Tamping-rod *c*, Pricker or Needle

203. **Charging and Firing.**—The hole, having been thoroughly cleaned, is ready to be charged. This consists in placing the charge at the extreme end, then filling the space in front by beating in clay or other non-inflammable material (*not* coal or coal dust; see C. M. R. Act, 1906) with the stemmer (fig. 140), provision being made for firing the charge. The operation of closing the hole in front of the charge is known as "tamping", "stemming", or "ramming". If no tamping were done, then in the case of gunpowder the charge would simply blow out of the hole without breaking down the rock, and while some explosives, as dynamite for example, can be fired without tamping, yet being confined in the hole makes the charge more effective. The conditions under which blasting is done are stated in G. R. 12 and *Explosives Order* (see also *Amendments and Special Rules*), and

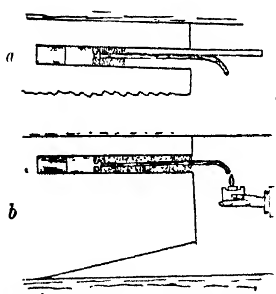


Fig. 140.—*a*, Stemming the Hole *b*, Lighting the Fuse

the reason for each rule must be clearly understood. The young reader will learn in the practical work of his class the use of the various appliances employed in blasting, and what is given here must be understood to be mere outline. In blasting operations the greatest care is necessary, and this must never be forgotten.

In firing gunpowder, or blasting powder, a *squib* or a *straw*, carefully filled with powder, or a *safety fuse* is used. Dynamite, gelignite, and other explosives, known as "high explosives" are fired by *detonation*, a *detonator* and safety fuse being employed In all cases the charge is gently placed in position at the back of the hole—G. R. 12 (*e*). If the explosive is blasting powder, and is to be fired with a squib or straw, the needle is inserted into the charge and the stemming done round the needle. The first 8 in. is tamped very lightly with soft material; as the process proceeds, the ramming is harder. At the end of the operation the needle is removed and the squib or straw placed in the hole thus left. Warning is given to all persons in the vicinity to retire; means are taken to prevent any person from approaching unawares; and the piece of "touch" or slow-burning paper which has been attached to the straw is ignited, the person who sets fire to this quickly retiring to a safe position.

Safety fuse.—We have already learnt something about this (§ 126). Examining a piece, we find it to consist of a thread of gunpowder surrounded by some protecting material, as flax, cotton, &c., and with an outer covering either of tape, coated with varnish, or gutta percha for damp or wet ground. The procedure is the same as in the case of the squib or straw, except that the end of the fuse is inserted into the charge, first being cut clean, and the hole stemmed round the fuse. The fuse burns at the rate of about 2½ or 3 ft. in a minute. In tamping, care

has to be taken not to injure the fuse, and this may happen if the tamping material contains gritty matter.

In using powder in wet ground special measures are necessary to keep it dry. Again, the cartridges may be in the form of "bobbins" of compressed powder, the hole running through the centre being larger at one end. In this case the bobbins are slung on to the fuse, the latter being attached to the innermost bobbin by doubling the end back into the larger opening, and gently pulling the fuse tight.

We come now to firing with a "detonator". This is a small cylinder or tube, about 1½ or 2 in. long and ¼ in. diameter, closed at one end, and containing a highly explosive substance, *fulminate of mercury*; or a mixture of fulminate of mercury and *chlorate of potassium*. The cylinder is generally made of copper. The end of the fuse is cut clean and inserted into the detonator until it reaches the fulminate. The upper part of the cap is then squeezed with a pair of nippers; the squeezing secures the fuse in position and serves to develop the power of the fulminate. If the charge is to be fired under water, the end of the detonator, where it joins the fuse, has to be made water-tight by means of grease or tar, thus preventing the fulminate from becoming damp. The detonator, with fuse attached, is now inserted into a cartridge, and the hole charged. The fuse explodes the fulminate, this in turn exploding the cartridge.

Detonators are numbered according to the amount of explosive mixture contained in them, different explosives requiring detonators of different degrees of strength. They are extremely dangerous appliances, and the utmost care is necessary in handling them. They must on no account be left lying about, and none must be "lost" (see *Explosives Order*). Great care is, of course, neces-

sary in introducing the charge into the hole and in tamping.

204. **Miss- and Hang-fires.**—The term *miss-fire* is applied when a shot for some reason fails to explode after the fuse, or straw, &c., has been ignited, and the term *hang-fire* when a longer than ordinary interval elapses between the lighting of the fuse and the exploding of the charge. Many accidents have occurred through persons returning to shots which they believed had missed fire, but which were merely "hang-fires". Here the minimum interval made compulsory by the *Special Rules* must, at least, be allowed to pass before any person enters the place. Many accidents have occurred too from men attempting to bore out shots which had missed fire (G. R. 12 (*e*)).

In ordinary blasting, miss-fires are liable to occur with squibs and straws, in some instances owing to improper filling. With squibs and straws, it should be observed, care is also necessary to guard against *premature* explosion. In the case of fuse a miss-fire may be due to the powder being damp or to the tamping having been carelessly done. With compressed powder care has to be taken to prevent the powdered core in the doubled end of the fuse from bearing against the other part of fuse. Reference has already been made to the connection between fuse and detonator and detonator and explosive. The cartridges forming the charge must be placed in contact, one with another. Miss-fires also occur from defects in fuse or detonator. For firing the charge a sufficiently strong detonator must always be used.

205. **Electric Blasting.**—Fig. 141 makes clear the method of shot-firing by electricity. At the end of the detonator is the mixture of fulminate of mercury and chlorate of potassium, and in front of this is the

"priming charge". The ends of the detonator wires are embedded in the priming. The priming and detonator wires form an "electrical fuse". When the hole has been stemmed the cable is connected to the

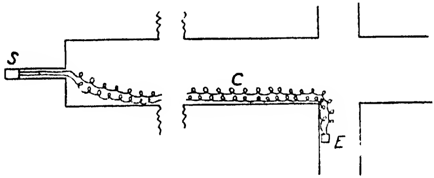


Fig 141 – Electric Shot-firing in Working Place

S, Shot, consisting of cartridge and special detonator (hole is shown unstemmed); C, cable; E, electric exploder and position of shot-firer The detonator has two insulated wires which project from hole, the cable is connected to these and to exploder

fuse wires and then to the exploder. When the handle of the latter is turned and the "button" pressed a current of electricity passes along the cable, causing the priming to become ignited and exploding the detonator, which in turn, we know, explodes the cartridge (see also *Explosives Order*).

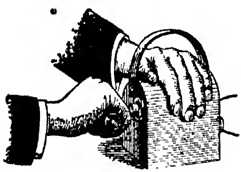


Fig. 142.—Magneto exploder ("Davis Derby")

There are two kinds of electrical fuses, *high-tension* and *low-tension*. In the former the ends or terminals of the wires embedded in the priming are a fraction of an inch apart. A high-tension exploder is used, and this causes a small current of electricity at a high pressure to pass along the cable; sparks leap across from the one terminal to the other, thus firing the priming. In the low-tension fuse the terminals of the wires are joined by

a piece of fine platinum wire. A low-tension exploder is employed, and when the circuit has been completed and handle turned, &c., a larger current of electricity at a lower pressure than in high tension flows along the cable. This current passing through the platinum wire makes it red-hot, thus igniting the priming. Sometimes low-tension fuses are termed "quantity" or "battery" fuses. They can be tested before using by means of an instrument called a *galvanometer*. High-tension fuses are sometimes termed "tension" or "machine" fuses.

Electric shot-firing is now very common in mines. It is safer (§ 126), and, besides possessing other advantages, there are fewer miss shots. Formerly there was believed to be no danger in approaching immediately a shot which had missed, after first detaching the cable from the exploder. Hang-fires, however, have been found to occur in electric blasting, and accordingly an interval must be allowed to pass before visiting the place. In all cases the cable must be at once detached from the exploder (*Explosives Order*). In stemming. care requires to be taken not to cut the wires or injure the covering material in any way (see as to using gritty matter). The ends of the fuse and cable wires must be scraped clean before connecting them, and they must be connected in a particular way.

206. **Simultaneous Blasting.**—The electric method is very convenient for firing a number of shots simultaneously, as in a sinking pit or stone mine. There are two ways of connecting the detonator wires to the cables—in *series* or in *parallel*. In series, one wire of the fuse of one shot hole is connected to one wire of the second shot hole; the other wire of the second hole is connected to one wire of the third hole, and so on. The cable wires are "coupled up" to the free wires of the first and last holes. In parallel, the wires of each

shot hole are connected directly to the cable, one wire of each fuse to one line of the cable, and the remaining wire of each fuse to the other line of the cable. A combination of the series and parallel arrangements is sometimes used. A number of shots can also be fired simultaneously, without the use of electricity, by means of *Bickford's Patent Volley Firer*. In this, instantaneous fuses, burning at the rate of 150 ft. per second, are ignited by means of ordinary fuse and patent igniter.

A disadvantage in simultaneous blasting is that the shots cannot be counted (§ 126), and it is not known until a return has been made to the place whether all have exploded. Care is therefore necessary. Accidents have occurred where two shots were being fired at the same time, in the ordinary way with squib or safety fuse, through the persons returning to the place after hearing only one report, thinking that the shots had exploded simultaneously.

207. **What an Explosive is and How it Acts.**—Our work in chemistry and physics enables us to understand the nature and the action of an explosive. We know that in ordinary combustion the oxygen of the air and a combustible are necessary. An explosive contains its own combustible or combustibles and also a substance which supplies the required oxygen; hence when we shut up the charge in the borehole and apply the necessary heat or shock to start the chemical action, combustion takes place. But that is not all. In the explosive there is so much of the oxygen-bearing substance that the combustion, instead of going on more or less slowly, as in the case of coal burning in a fire, for example, is extremely rapid, and there is an explosion.

Now in regard to the *action* of an explosive, the matter, we assume, is indestructible, and so when the explo-

sive is fired it is converted into gases. These gases, if free, would occupy a volume hundreds of times that of the explosive; but being confined in the small space of the borehole they exert an enormous pressure and therefore break down or burst out the rock. All this, the combustion of the explosives, the pressure of the gases on the containing walls, and the breaking down of the rock, it must be remembered, takes place almost instantaneously.

The gases exert a pressure equally in all directions (§ 178), and break away, as we say, "the ground in the line of least resistance", or, in other words, the ground in the weakest direction. The knowledge of this fact assists us in placing shots (§ 148), and shows the importance, in doing so, of taking note of slips, partings, and joints. It also shows the necessity for tamping holes, although high explosives, as dynamite, are so rapid in their action that a very little tamping suffices. Dynamite is much more rapid in its action than gunpowder, hence when exploded on the ground it makes a large hole, whereas the force of the gunpowder is expended on the air. Some people therefore say that dynamite when exploding "strikes down", meaning that it does so more than it "strikes up", or in any other direction. That, we can see, is wrong, as the gases into which the explosive is converted exert a pressure "equally in all directions". The action of the dynamite is so rapid that when fired on the ground there is no time for the force to be spent on the air, or "in the line of least resistance" as in the case of the gunpowder. If the gunpowder be confined, as by placing a heavy weight upon it, a hole will be made in the ground, the latter now being in the line of least resistance.

208. **Composition of Explosives.**—We need consider only gunpowder, blasting powder, and dynamite. *Gunpowder,*

it has been seen, is a mixture of charcoal, sulphur, and saltpetre. There is 15 per cent charcoal, 10 per cent sulphur, and 75 per cent saltpetre. If we take a little of each of these substances and mix them together in the proportions named we shall have gunpowder. Other names for saltpetre are "nitre" and "potassium nitrate". It is a chemical compound of potassium, nitrogen, and oxygen, and is, it will be seen, the oxygen-bearing substance of the explosive. Charcoal and sulphur are the combustibles

Blasting powder differs from gunpowder in that there is less saltpetre and more of the other substances. There is no better explosive for coal than gunpowder (or blasting powder), because, having a slow-rending action, it does not smash the coal. It is, however, not allowed to be used in some mines, on account of the large amount of flame produced during the combustion, and also on account of the large quantity of the very dangerous gas, white-damp, which is produced (chap. xxxi).

Dynamite.—The composition of dynamite is 75 per cent nitroglycerine and 25 per cent kieselguhr. It is the nitroglycerine that is the explosive. This, however, is a liquid too dangerous to be used alone. The kieselguhr, a siliceous earth, absorbs the nitroglycerine. Dynamite, therefore, in its usual state is a plastic substance. It is of a reddish colour.

Explosives which have nitroglycerine as a base are termed "nitroglycerine explosives", and include, among others, blasting gelatine, gelatine-dynamite, gelignite, and, of course, dynamite. Nitroglycerine explosives freeze and become hard in cold weather. They must then be thawed, as to use them in a frozen condition is highly dangerous. Lives have been lost in consequence of ignorant persons trying to soften the cartridges by such means as heating them before a fire, in an oven,

on a stove or steam cylinder, or by carrying the cartridges about with them. The thawing must be done in special warming pans and according to instructions. These and all other explosives must only be used, as already mentioned, in accordance with instructions.

209. **Blown-out Shots.**—A blown-out shot occurs when the explosive "blows out" of the hole without doing any work. There is much flame and concussion, and a piece may be blown off the mouth of the hole. The danger of a blown-out shot is that it may give rise to an explosion either of firedamp or coal dust. This is also the case with an overcharged shot.

Everybody has heard of firedamp and of the explosions that sometimes arise from its presence in the air of coal mines; but it seems hardly credible that coal dust should be able to cause an explosion. To do so the dust must be dry and in a sufficiently fine state. If such dust is subjected to some form of violent inflammation, which both raises and ignites it, then there is an explosion. This has been shown by firing a cannon in a disused shaft in which coal dust was placed. The result of such experiments and of the careful examination of mines after explosions have occurred in them, is that experts now believe that many of the great explosions in pits in recent times have been due not to firedamp, but to coal dust; and that, in any case, coal dust in the mine will intensify and extend a firedamp explosion. We shall learn fully about firedamp, and return to the subject of coal dust, in chap. xxxii, but meantime we must note the danger in blasting to which the presence of these substances gives rise, and the precautions necessary to secure safety, so far as possible.

It will be seen that in the case of a blown-out shot the line of least resistance is through the borehole, and it is

also apparent that every care must be taken to avoid them. Careless or inefficient tamping may be the cause, or the shot being in the solid. In all cases the end of the shot hole must not be at a greater depth than the back of the under-cutting, and in boring, the hole must not be slanted so that the end is in the solid side coal. In proportioning the charge to the work to be done, practice is necessary, but a theoretical knowledge is very helpful, and care and observation do the rest. What has been stated in the present and two preceding paragraphs makes clear the requirements of G.R. 12 and *Explosives in Coal Mines Order* as to firing shots where there is gas or the place is dry and dusty; and also as to not stemming a hole with coal or coal dust.

210. **Permitted Explosives.**—To reduce the danger of the ignition of inflammable gas and coal dust in some mines only certain explosives, hence termed *permitted explosives*, are now allowed to be used, and then only under certain conditions (see *Explosives Order*). These are explosives the composition of which is such as to render them less likely than gunpowder to inflame gas or coal dust when fired; but it must be borne in mind that no explosive is absolutely safe. The *permitted explosives* have been called "non-flaming explosives", but this term should not be used.

The Explosives Order contains the names of the permitted explosives, a statement as to the composition of each, and the conditions under which each must be used, including the number of the detonator. When a manufacturer has an explosive which he thinks might be used in all mines, he applies to the authorities to have it tested. This is done at the Government Testing Station at Woolwich. If found to satisfy the standard conditions, the explosive is placed on the "list of permitted explosives". Again, if an explosive after having

been placed on the list is found not to come up to the standard of safety its use is prohibited. Thus the number of permitted explosives alters, and new orders are issued from the Home Office.

211. **Substitutes for Blasting.**—We see from the preceding paragraphs that only certain explosives are allowed to be used in certain mines; and it has been proposed to prohibit blasting entirely, using such substitutes as the lime cartridge and wedge.

The Lime Cartridge.—The coal is undercut and drill-hole bored in the usual way. The cartridges, of ordinary mountain limestone which has been calcined, then ground to powder, and compressed by hydraulic power, have a groove which fits a pipe about ½ in. in diameter. The pipe is perforated at one end, and is placed in the hole with the perforated end to the back. The cartridges are put into the hole and the latter stemmed. Water is now forced in by connecting a small force pump to the outer end of the pipe. The pump is then removed. Steam is formed, as we saw in the experiment (§ 196); with the water the lime expands greatly; and the coal is broken down.

The lime cartridge is not suitable for coal with openings, and has other objections. It has therefore never come into general use.

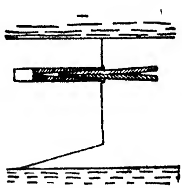


Fig 143.—Patent Multiple Wedge, showing two wedges inserted

Wedges.—We have already taken note as to the use of the ordinary wedge and hammer in breaking down coal. In fig. 143 are seen two pieces, called "feathers", extending from near the back end of the hole to the mouth, and between them are two wedges. The feathers are tapered, half-rounded pieces of iron, with flat sides next the

wedges. The hole is drilled as in blasting, and the feathers are placed in it with the thin end of each outwards; the wedges are then driven in between. What is known as the *wedge and feathers* or *plug and feathers* consists of two feathers and one wedge. In *Elliot's Patent Multiple Wedge* there are three wedges and two feathers. The wedges are driven in with a hammer, and if the first two (fig. 143) do not break down the coal, then the third is forced in between them. The coal breaks down at the end of the feathers. Other wedges are *Burnett's Roller Wedge* and *Hydraulic Wedges*.

CHAPTER XXXI

GASES MET WITH IN COAL MINES

Carbonic Acid Gas—Carbonic Oxide—Sulphuretted Hydrogen

As has been indicated (§ 187), four gases are likely to be met with in the air of coal mines.

212. **Carbonic Acid Gas.**—We have already made the acquaintance of this gas. Chemists call it *carbon dioxide* and *carbonic anhydride*; *carbonic acid gas* is its common name. Miners call it chokedamp.

Carbon dioxide is a chemical compound of carbon and oxygen. The molecule consists of 1 atom of carbon and 2 atoms of oxygen. Chemists denote this by writing, instead of the name of the gas, CO_2, which is called a *chemical symbol or formula*. We have learnt what a molecule is. Now small as molecules are chemists believe them to be made up of still smaller particles called atoms, but an atom cannot exist independently, as can a molecule. It is defined as the smallest portion of matter that

can enter into chemical combination, and to form each molecule of carbon dioxide, 1 atom of carbon has to combine with 2 atoms of oxygen.

The presence of carbon dioxide in mines is unavoidable, this gas being produced, as we have seen, by the breathing of persons and horses and the burning of lights. It is also produced by the decomposition of timber; in blasting; at underground fires, and, as will be seen in the next chapter, in explosions of firedamp. It is given off by coal as the seam is worked.

Air containing more than a certain proportion of this gas is harmful (§ 200). Certain percentages produce panting, headaches, sleepiness, and death.

Carbonic acid gas has no colour, therefore it cannot be seen. It possesses a slightly acid taste and smell, but too faint to serve as a means for its detection.

Its presence is made known by its effect on lights. Pure carbon dioxide at once extinguishes lights, and the effect is the same, even if the gas is mixed largely with air. A lamp, then, either burns feebly or is extinguished according to the percentage of carbonic acid gas present in the air. If there is a difficulty in keeping the light in, then the gas is present to a dangerous extent, and the person should at once withdraw.

It has been explained that this gas is about one and a half times heavier than air. Accumulations of it, therefore, tend to sink down through the air, and gather in hollows and the lower parts of the workings of mines. Such places as sumps, the bottoms of sinking pits and wells require to be carefully tested, even if a brisk current of air is circulating.

Preparation.—The apparatus is the same as is used in the preparation of hydrogen (fig. 134). Instead of zinc a few marble chips are put into the bottle, covered with water, as was the zinc, and dilute hydrochloric acid added

little by little. The marble (a compound of calcium, carbon, and oxygen) is decomposed and carbonic gas evolved. Though very soluble in water, the gas may be collected in the same way as oxygen and hydrogen. The cylinders when filled are placed mouth up, the glass discs covering the latter. Being so much heavier than air, this gas may be collected by the displacement of air, the end of the delivery-tube dipping into a cylinder containing air instead of into water.

Experiments to illustrate Properties of Carbon Dioxide

(1) *It is incombustible and does not support combustion.* The gas does not burn when a lighted taper is applied to it, and the taper is extinguished on being put into the cylinder.

(2) *Weight.* (*a*) See as to method of collecting by displacement of air.

(*b*) A lighted taper introduced into a cylinder continues to burn, showing that there is no carbon dioxide present. A cylinder of the gas is now emptied into first cylinder (pouring the gas down like water) and light again introduced. Light is extinguished, carbonic acid gas being now present.

(*c*) A beaker can be counterpoised on a balance and carbonic acid gas poured into the beaker; the pan carrying the beaker sinks down.

(3) *Carbonic acid gas turns lime water "milky".*—Pour a little clear lime water into a cylinder and shake. There is no change; no carbonic acid gas present. Pour carbonic acid gas into cylinder, and again shake. Lime water becomes turbid. The result of this experiment, it will be seen, verifies the conclusions of two previous experiments—that carbon dioxide is produced by the burning of coal, &c., in air (§ 189), and by breathing (§ 200.)

213. **Blackdamp, Chokedamp, Stife or Stythe.**—Formerly,

when miners used any of these terms, carbonic acid gas was understood to be the gas meant. Now "black-damp" denotes a mixture of nitrogen and carbonic acid gas. The effect of the mixture on those breathing it and on lights is similar to that of carbonic acid gas, but, nitrogen being lighter than air, blackdamp weighs less than pure carbonic acid gas, and may even be lighter than air if it contains a large percentage of nitrogen, or if mixed with a little firedamp. It is very important to know this, as a light which burns near the floor may be extinguished near the roof, owing to the presence of blackdamp.

214. **Carbonic Oxide** (also called *carbon monoxide* and *whitedamp*, the latter being a mining name).—This gas, like chokedamp, is a chemical compound of carbon and oxygen, but contains only half as much oxygen as does chokedamp (§ 193). This is shown by its chemical symbol or formula, CO, denoting that the molecule consists of 1 atom of carbon combined with 1 of oxygen.

Whitedamp is an extremely poisonous gas. Minute proportions in air are dangerous. Happily it is not present to any extent in the air of mines under ordinary circumstances. It is produced in blasting, is found in afterdamp (chap. xxxii), and is given off at underground fires. Wherever carbon is burnt in an unlimited supply of air there is complete combustion, and carbon dioxide is formed; where the supply of air is limited the combustion is incomplete, and carbon monoxide is produced. The presence of both blackdamp and whitedamp, then, may be suspected in cases of underground fires.

Chokedamp, it has been seen, is not combustible, but if a light is applied to the mouth of a cylinder of white-damp the gas takes fire and burns with a blue flame, forming carbonic acid gas. The blue flame often seen at the top of an ordinary fire is that of burning carbon

monoxide. A mixture of whitedamp and oxygen or air in certain proportions is explosive.

This gas has neither colour nor taste, and may be described as possessing no smell. In its pure state it at once extinguishes lights. There is no ready way of detecting its presence. In special circumstances a mouse, carried in a cage, is used. The gas affects a mouse much sooner than a man, and warning is thus given of the presence of the gas. CO is little lighter than air (§ 187).

Preparation, &c.—Only a small quantity of this dangerous gas can be prepared. Place in a test tube a little *sodium formate*, add some strong sulphuric acid, and close mouth of tube with a cork fitted with a delivery-tube. Collect over water one or two test-tubefuls of the gas, avoiding any escape. On adding a little clear lime water to one of the test tubes, closing the mouth and shaking, there is no change. On applying a light the gas burns with a blue flame, and on again shaking the tube the lime water becomes turbid, showing that the burning of CO in air produces CO_2. It can be shown that the gas does not support combustion by introducing a light into it, the light being extinguished.

215. **Sulphuretted Hydrogen**.—This gas is also called *hydrogen sulphide*. Miners term it *stinkdamp*. It is a compound of sulphur and hydrogen. Its chemical symbol is H_2S, indicating that each molecule consists of 2 atoms of hydrogen combined with 1 atom of sulphur.

Sulphuretted hydrogen is without colour, but has a very strong smell—like that of a rotten egg—the offensive smell of a bad egg being due to the presence of this gas within the shell. The smell serves as a means of detecting the gas.

This gas, like carbon monoxide, burns with a blue flame (but does not produce carbon dioxide); extinguishes lights; and is very poisonous. Like carbon monoxide,

too, it is seldom present in the air of mines to any great extent. It is produced by the blasting of gunpowder and blasting powder and from the decomposition of substances containing sulphur, such as iron pyrites, in contact with water. It is given off during underground fires, giving rise to the smell known as *gob-stink* or *gob-fire*, which warns us of the breaking out of such fires, and of the presence of whitedamp. Sulphuretted hydrogen is slightly heavier than air (§ 187).

Preparation, &c.—Only a small quantity of this gas need be prepared. A small fragment of iron sulphide (a compound of iron and sulphur) is put into a test tube and a little dilute hydrochloric or sulphuric acid added. Sulphuretted hydrogen is evolved, as shown by the offensive smell. If a lighted taper be applied to the mouth of the jar the gas burns.

CHAPTER XXXII

GASES MET WITH IN COAL MINES—(*Continued*) —COAL DUST

Marsh Gas (firedamp)—Coal Dust

216. **Marsh Gas.**—Other names for this gas are *carburetted hydrogen, methane*, and *methyl hydride*. The names *firedamp, fire*, and *gas* are also given to it, but firedamp is really a mechanical mixture of gases, and in some cases possesses a smell by which its presence can be detected. On the other hand, pure carburetted hydrogen has no smell. The reason why marsh gas is regarded as firedamp is because it forms such a large proportion of it, sometimes as much as 99 per cent. Firedamp is heavier than marsh gas, its average specific

gravity (§ 187) having been found to be about 0·7. Firedamp is the most important gas found in mines, hence the name "gas". Marsh gas is a chemical compound of carbon and hydrogen. Its chemical symbol or formula is CH_4, indicating that the molecule consists of 1 atom of carbon combined with 4 atoms of hydrogen. For practical purposes we may regard firedamp and marsh gas as being identical.

Firedamp is pent up in the pores of the coal, and is given off as the seam is worked. It is a product of the decomposition of vegetable matter, and this accounts for its presence in coal seams. The name "marsh gas" arises from the fact that it is found in marshy places, bubbles of the gas ascending to the surface if the vegetable deposit at the bottom of a pool be poked with a stick. It is contained in some seams at great pressures. Different tests have been made, one pressure recorded being a little under 461 lb. per square inch.

Usually the firedamp exudes quietly from the coal, or with a sort of humming or singing noise. Where the pressure is great, pieces of coal are sometimes forced off the face. *Blowers* also occur where the pressure is great, the gas "blowing out", or issuing with a hissing sound, in a more or less steady stream. Blowers may be small or large. In many cases *outbursts* have taken place. These are sudden outrushes of gas which has been imprisoned in the seam. The gas bursts out the coal when the face approaches sufficiently near it. Outbursts from the roofs and floors of seams have also occurred. In seams liable to outbursts precautions are taken to guard against their occurrence.

This gas is not found at all in some seams, or only to a small extent, having probably escaped into the rocks above or to the surface. In others it occurs abundantly. Generally the deepest seams contain the largest quantity.

When a seam contains much firedamp it is said to be "fiery". Sometimes in opening up a new district a seam is found to be fiery, and the remaining seams not so. This is probably due to the firedamp contained in the latter seams finding its way to the one first worked.

Firedamp, being little more than half the weight of air, tends to lodge in cavities in the roof, and in the higher parts of the workings of mines. Sometimes special means have to be adopted to force it out of such places.

This gas has neither colour nor taste and does not support combustion. Breathed in the pure state it causes death, but is comparatively harmless when present in the air in small quantities. It is especially dangerous because when present in the air in certain proportions it forms explosive mixtures, the name "firedamp" being given to it for this reason.

The difference between ordinary combustion and that in which we have an explosion has been explained (§ 207). Now if we apply a light to a cylinder of firedamp the gas at the mouth of the cylinder, or in contact with the air, burns, giving us an instance of more or less slow burning, or ordinary combustion. On the other hand, if we introduce into a soda-water bottle air and firedamp, so that there is a certain proportion of each present, and apply a light to the mouth of the bottle, there is an explosion. Here the combustible substance (the firedamp) and the supporter of combustion (the oxygen of the air) are so intimately mixed, the molecules of each gas existing side by side, that when the light is applied the burning or combustion takes place at once and we have an explosion.

In the mine the explosive mixture of gases becomes ignited by the flame of a lamp or otherwise, and the force of the explosion is in some cases very great.

Timber is displaced, causing falls of roof; and doors, stoppings, and air-crossings (chap. xxxiv) are blown out. The most explosive mixture contains about $9\frac{1}{2}$ per cent of firedamp (or about $10\frac{1}{2}$ volumes of air to 1 of firedamp), these proportions being such that there is just the necessary amount of combustible substance and supporter of combustion to cause perfect combustion. As the proportion of firedamp increases or decreases, the explosive action becomes less and less, until, when the percentage of firedamp is below 6 or above 15, the mixture will no longer explode. As we shall see in the chapter on "Lighting", the presence of firedamp in the mine is detected by means of the "safety lamp".

Afterdamp.—The products of the combustion of firedamp are carbon dioxide and water vapour or steam (which soon condenses into water), the carbon combining with oxygen to form the CO_2, and the hydrogen with oxygen to form the water vapour (§ 189). The nitrogen of the air is left. Usually carbonic oxide is also present, and the mixture of gases resulting from the explosion of firedamp and air, with or without coal dust (or of coal dust without firedamp), can thus be seen to be of a very deadly nature. It is termed *afterdamp.* Of the lives lost in colliery explosions the greater number are due to carbon-monoxide poisoning. The danger from the presence of this gas, which, it has been shown, requires special means for its detection, has, then, to be kept in mind in all rescue operations. See also § 215, underground fires.

Preparation.—Marsh gas is prepared by heating strongly in an iron tube, closed at one end and fitted with cork and delivery-tube, and fixed to a stand, a mixture formed of *sodium acetate* with about three times its weight of *soda lime.* The gas is collected in

the same way as hydrogen, similar precautions being taken to guard against explosions.

Experiments to Illustrate Properties.—(1) *To show inflammability, &c.*—Apply a light to a cylinder of the gas as in the case of hydrogen. Observe the non-luminosity of the flame. After the burning has ceased, pour a little clear lime water into the jar and shake. The lime water becomes milky, proving that carbonic acid gas has been produced. As the gas burns in the jar, moisture is deposited on the sides.

(2) *To show lightness.*—Proceed as in the case of hydrogen.

(3) *To show that a mixture of firedamp and air will explode.*—Mix in a stout soda-water bottle, or explosion tube, one volume of marsh gas and ten volumes of air and apply a light. The mixture explodes. To guard against accident the bottle is wrapped in a towel.

217. **Coal Dust.**—We learnt about this in chap. xxx. If a piece of coal be powdered and some of the particles thrown on to a bright fire, they sparkle like gunpowder and are instantly consumed. Coal dust is therefore an inflammable substance, as are many other dusts. Thus explosions have occurred in flour mills. In the mine the especially dangerous coal dust is the fine dust found on the roof, sides, and timbers. It is so fine that when disturbed it floats in the air and is therefore more easily ignited. The particles of coal dust contain combustible gases, as methane, and these are driven off when the temperature of the dust is raised. This shows the danger of tamping shot holes with coal or coal dust.

From what appears, then, in the present chapter and in chap. xxx, it is plain that in a mine there may be explosions, (1) due to firedamp alone, (2) due to firedamp and coal dust, and (3) due to coal dust without any admixture of firedamp. In regard to explosions

from coal dust alone, these, it is believed, can only take place under exceptional circumstances; but as such circumstances, as we have seen, may arise in blasting, the necessity for the very strict rules already referred to is apparent.

In some mines the dust on the main roads is kept damp by means of watering tubs, or pipes led along the roads. In the latter case compressed air is sometimes used with the water to give a fine spray at the point of discharge. Sometimes part of the dust is removed, to render less damping necessary. Other methods of counteracting or minimizing the danger are also in use.

CHAPTER XXXIII

ATMOSPHERIC PRESSURE

The Barometer—Pumps—The Siphon.

218. **Pressure of the Atmosphere.**—The *atmosphere* is the name applied to the air surrounding the earth. It is sometimes described as forming an ocean of air at the bottom of which we live and move. How far upwards the atmosphere extends is not known, but from the evidence afforded by meteors the distance is believed to be not less than from 200 to 300 miles.

Now, since air has weight, or, in other words, is subject to the pull of gravity, this "ocean of air", or the atmosphere (to call it by its proper name), must exert a pressure on all objects exposed to it. This pressure is known as the *pressure of the atmosphere* or *atmospheric pressure*. At sea level it amounts to about 15 lb. on each square inch (more correctly 14·7 lb. per

square inch) or nearly a ton per square foot. Accordingly, on the body of a man of average size there is an atmospheric pressure of about 14 tons.

Under ordinary circumstances no one feels the atmospheric pressure, because every person's body contains gases and these exert a pressure which exactly balances the atmospheric pressure. Then the atmospheric pressure is exerted equally in all directions — upwards, downwards, &c.—and, of course, equal pressures acting in opposite directions (or against each other) neutralize each other, and a person can stand still or move about freely just as if no atmospheric pressure existed. When wind blows, however, we do feel it (and wind is just air in motion), because the pressure is then greater in one direction than in another. Also we should feel a difference if we were to ascend a high mountain or be carried up to a considerable height in a balloon, because the atmospheric pressure decreases with the height, and our bodies being constructed to sustain a normal atmospheric pressure of about 15 lb. per square inch, a greatly reduced pressure affects us injuriously, as would also, of course, a greatly increased pressure (§ 123).

It having been mentioned that the atmospheric pressure decreases with the height, we will do well to note that this is only what is to be expected. The higher we ascend the more air is left below, and the upper air having, therefore, less weight of air above, is thinner, or more rarefied, and consequently exerts a smaller pressure than the air farther down. On the top of Mont Blanc, or about 3 miles above sea level, the pressure of the atmosphere is only about 7½ lb. per square inch, while at a height of about 7 miles the air is so thin that it is impossible to breathe. As we descend the pressure gradually increases until at sea level it is, as before stated, about 15 lb. per square inch.

Many different experiments can be performed to prove the existence of atmospheric pressure:—

(1) Into a cylinder about 1 ft. long and 6 in. diameter, made of thin tin, and having a tube soldered into an opening in one end, a little water is put. The cylinder is set upon a tripod over a bunsen burner or spirit lamp and heat applied until the water has been boiling for a minute or two, the steam escaping at the tube. A cork is now fitted tightly into the tube and the burner or lamp removed. After a short time the sides of the cylinder are crushed in.

Nothing happens at first, because the pressure of the air inside the cylinder balances the pressure on the outside. Heating the cylinder and converting the water into steam expels the air. After the cork is put into the tube and the source of heat removed the steam within the cylinder condenses, and there being now little or no pressure inside to support the sides, which are themselves not thick enough to withstand the atmospheric pressure outside, the cylinder is crushed. This experiment really illustrates that the atmospheric pressure acts in all directions.

(2) From the foregoing it will be evident that the experiment with the bladder (§ 178) also illustrates atmospheric pressure.

(3) Take a glass tumbler with a smooth edge and fill it to the brim with water. Place a sheet of cardboard over the mouth of the tumbler, taking care to press it down very closely. Now with one hand turn the tumbler mouth down, keeping the cardboard in its place with the other. When the tumbler has been inverted, remove the hand from the cardboard. It will be found that the latter remains in its place, and that, consequently, the water does not run out. This is owing to the atmospheric pressure, which, acting upwards on

the under side of the cardboard, supports both it and the water. This experiment shows that pressure is exerted in an upward direction.

219. **Measurement of the Atmospheric Pressure.**—The

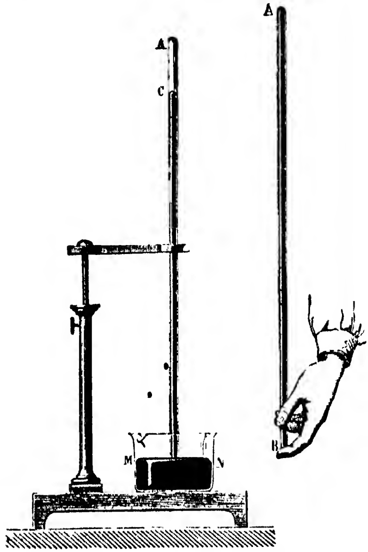


Fig 144. -Torricellian Experiment

experiments described in the preceding paragraphs merely show that the atmosphere does exert pressure. They do not measure the amount of that pressure. To do this an instrument called a *barometer* is required. The following experiment enables us to understand the construction and action of the barometer:—

Take a glass tube about 36 in. long and closed at one end (AB, fig. 144). Fill it with mercury. Place the finger over the open end of the tube to prevent the mercury from running out, and turn the tube mouth down. Dip the open end, still covered by the finger, into mercury contained in a small glass cistern or basin; when completely immersed, withdraw the finger. Now note what happens. The tube being held vertically, the mercury might be expected to run out into the basin, but does not. It falls a short distance, but a long column remains. Now what supports this column? The answer is, that it is the atmospheric pressure acting on the surface of the mercury in the basin. When the tube is filled with mercury all the air contained in it is driven out. Placing the finger over the mouth of the tube prevents any air from entering, and, consequently, when the mercury sinks down after withdrawal of the finger, the clear space AC at the top of the tube is completely empty. There being thus no pressure on the top of the mercury in the tube, the atmospheric pressure, acting on the surface of the mercury in the basin, keeps the column standing in the tube. Because the space at the top of the tube is quite empty it is called a *vacuum*, and because this experiment was first performed (in 1643) by Torricelli, an Italian philosopher, it is known as a *Torricellian vacuum.*

Now some think at first that since there is no air and no pressure above the column of mercury in the tube the atmospheric pressure ought to force up the mercury and fill the whole tube, but that is a mistake. If the atmospheric pressure could fill the whole tube with mercury it would do so, but it is not able. The reason is, that mercury is a very heavy substance, about thirteen and a half times heavier than water, and, of course, the atmosphere is only able to support a column

equal in weight to its own pressure. The height of the column at sea level is found to be on the average about 30 in., corresponding to an atmospheric pressure of 14·7 lb. per square inch.

If the length of the tube were *less* than the height of the column of mercury which the atmosphere is able to support, then no vacuum would be formed; but such a tube would be useless, as we could not get from it the true height of the mercurial column. Then the tube must be longer than 30 in., because, owing to changes in the temperature of the air and in the amount of watery vapour contained in it, the atmospheric pressure is not always the same at the same place and may be more than 14·7 lb. per square inch, the column of mercury then standing higher than 30 in. In this country the changes of atmospheric pressure are such that the height of the column of mercury varies from about 28 to 31 in.

It is easy now to understand how the amount of the atmospheric pressure is ascertained. The column of mercury in the tube being supported by the atmospheric pressure — rising when the atmospheric pressure increases and falling when it decreases—is always a measure of that pressure, and all we require, to be able to tell the atmospheric pressure in inches of mercurial column, is to have a tube such as the one described fitted to a wooden frame, and having a scale marked in inches and tenths by which the height of the mercurial column can be read. Such an arrangement constitutes an ordinary barometer, hence we say a barometer is an instrument for measuring the atmospheric pressure.

Wheel, &c., Barometers.—Sometimes by a modification in the construction of the barometer a pointer is made to revolve on a dial, and we read the inches of mercurial

column from a scale marked round part of the circumference. This is termed a *wheel barometer*. Then, instead of mercury, water might be used to fill the tube. But since water is about thirteen and a half times lighter than mercury the atmospheric pressure could support a column thirteen and a half times higher than the column of mercury, or about 34 ft. at sea level. The tube, then, for a water barometer could not be less than 34 ft. high, and that would be inconvenient. In another barometer, called the *aneroid barometer*, no mercury or other liquid is used.

220. **Reading the Barometer.**—Ordinarily people use the terms "barometer" and "glass" instead of mercurial column. Thus, if the atmospheric pressure is increasing, and the mercury consequently rising in the tube, we say "the barometer is rising", or "the glass is going up", &c. Or, if the mercurial column is falling (due to decrease of atmospheric pressure), we say "the barometer is falling", or "the glass is going down", &c. Then when the atmospheric pressure remains unchanged for a time, so that the mercuriul column neither rises nor falls, we say "the glass is steady", or "the barometer is steady", &c. Again, such phrases as "the barometer is high", "the glass is high", &c., mean that the mercurial column is standing high (denoting a high atmospheric pressure), the converse phrases "the barometer is low", &c., being used when the mercurial column is low (denoting a low atmospheric pressure).

Taking the height of the mercurial column is called "reading the barometer", the determination or number of inches at any time being termed a "reading". Usually before reading the barometer we tap it gently. This is to loosen the mercury, the surface of which may be adhering to the sides of the tube, and thus preventing the column from adjusting itself to the level required

by the atmospheric pressure. Tapping the barometer enables the correct reading to be obtained.

Now when a person reads the barometer and finds it to be standing at, say, 29·5 in., or any number of inches, the corresponding atmospheric pressure can be obtained by multiplying the number of inches by 0·49, the weight of a cubic inch of mercury. Thus, if the height of the mercurial column were 30 in., then the corresponding atmospheric pressure would be $30 \times 0{\cdot}49 = 14{\cdot}7$ lb. per square inch. But usually no one troubles to do this. All we require to know is whether the atmospheric pressure is high or low, or is increasing or decreasing, and therefore it is sufficient merely to note the readings of the barometer. Thus, if the barometer reads 29·5 in., and, later on, say 29·8 in., then 30 in., we know the atmospheric pressure is increasing, and, similarly, if it reads 30 in., or any number of inches, and then on tapping, the mercury stands at a lower level, we know the atmospheric pressure is decreasing. By observations of the barometer at brief intervals it can be seen that the atmospheric pressure is continually changing.

221. **Measurement of Heights by the Barometer.**—The atmospheric pressure, as has been explained, decreasing with the height, there is less and less pressure, as we ascend, to support the mercurial column, and therefore the latter grows gradually shorter. Hence if a barometer be read at sea level, and then at the top of a mountain, or other elevated position, the second reading will be found to be less than the first. Again, when a barometer is taken down a deep shaft the reading at the bottom of the shaft is greater than at the top. Thus the barometer can be used for measuring heights. Roughly, for each 900 ft. of ascent the barometer falls 1 in., and for each 900 ft. of descent it rises 1 in.

222. **The Barometer at Mines.**—See G.R. 33. We know

that when the pressure on a gas is reduced the gas expands. Accordingly, when the atmospheric pressure decreases, the gases contained in the goaves or wastes, &c., tend to come out into the workings and roadways of the mines. The idea, then, is that the barometer, by indicating the atmospheric pressure, gives warning of when this is likely to take place. The gases, however, being so much lighter than mercury (firedamp is about 20,000 times lighter), are more sensitive and may respond to the change of atmospheric pressure before this can be seen by the falling of the mercurial column in the barometer, and therefore the latter cannot be relied upon as *forewarning* the issue of the gases. Then many explosions have occurred in mines when the barometer was high, or when it was rising, as well as when it was low, or falling; and accordingly the discipline of the mine has to be maintained at all times, every person observing faithfully the rules. In the newspapers *Colliery Warnings* appear at intervals, referring to the state of the atmosphere as regards pressure and the dryness of the air, and warning miners to be on their guard against explosions of firedamp and coal dust, but, as has been said, proper care is necessary *at all times*.

When the barometer is low, a less weight of air passes into the mine in a given time, and such also is the case when the *temperature* (as shown by the *thermometer*) is high. Usually when the thermometer rises the barometer falls, and vice versa.

223. **Pumps.**—We must now consider the action of the suction and force pumps, and also that of the siphon.

The *common* or *suction pump* is shown in fig. 145; B is the *bucket*, a piston having two valves or lids opening upwards; WB is the *working barrel* or part of the pump in which the bucket is moved up and down

by means of the *pump-rod* R—it is an air-tight cylinder into which the bucket fits closely; S is the *spout* or *delivery pipe*; and SP the *suction pipe*, at the top of which is the *suction valve* or *clack*, this, like the bucket valves, opening upwards. At L is seen the surface of the water to be pumped.

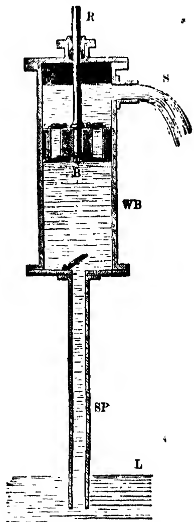


Fig. 145.—Common Pump

Now the water in the working barrel is carried up by the bucket in its upward stroke, flowing out at the spout; but evidently some force is necessary to raise the water into the working barrel. This force is supplied by the atmospheric pressure, which we have seen is able, at sea level, or when equal to about 14·7 lb. per square inch, to support a column of mercury 30 in. high, or a column of water 34 ft. high.

Suppose the bucket to be at the bottom of its stroke, and the pump to be full of air at atmospheric pressure, the water in the suction pipe, therefore, standing at the level L. Now let the bucket begin its upstroke. A vacuum tends to be formed below it, and the pressure of the air in the suction pipe forcing open the suction valve, some of the air passes up through into the working barrel. The air thus expanding, its pressure is reduced to less than that of the atmosphere acting on the surface of the water outside at L, and the water is consequently forced higher up the suction pipe. On the bucket

commencing its downstroke the suction valve closes, and the air which passed into the working barrel, being thus imprisoned, forces open the valves of the descending bucket and escapes up through. The bucket valves close on the upward stroke being commenced, and the air which passed up through it is lifted with the bucket. A vacuum tends to be formed underneath the ascending bucket, as before, and more air passes into the working barrel from the suction pipe, the pressure being thus still further reduced, and the atmospheric pressure, which continues steadily to act on the surface of the water to be pumped, forcing the water higher up the suction pipe.

Thus with each upward stroke of the bucket the air is taken out of the pump and the water forced higher and higher, until it and not air passes into the working barrel. Water is now raised by the bucket—being forced up into the working barrel by the atmospheric pressure during each upstroke and carried up by the bucket in the following upstroke. This continues as long as the pump is working. Of course if the pump is full of water at the start it will begin to pump water right off, and not air.

Thus we see the action of the common or suction pump depends upon the atmospheric pressure, Torricelli's experiment showing us the height to which the atmospheric pressure can force up the water, namely, the height of the water barometer, or about 34 ft. The reason why water cannot rise higher in a pump than this was not known until the time of Torricelli's experiment. In practice it is found that the top of the working barrel must not be as much as about 34 ft. above the lowest level of the water to be pumped. This is owing to the loss of vacuum due to air entering with the water, and also through the joints of the pipes, if these are not

perfectly air-tight. Then there is the friction of the valves and of the water in the pipes. About 28 ft. in practice is the height to which the atmospheric pressure can force up the water, and in order that the pump may work well the top of the working barrel is not placed more than about 21 ft. above the lowest surface of the water. This height is sometimes termed *the height of the suction*, and, of course, will be less in an elevated position than at sea level, because, as we have seen, the atmospheric pressure decreases with the height.

In fig. 145 the delivery pipe is shown at the top of the working barrel, but in large pumps fixed in mine shafts pipes, joined end to end, extend from the top of the working barrel up the shaft. These are called *delivery pipes*, *stocks*, or *trees*. At the top of the working barrel is the *bucket door-piece*, the door (termed the *bucket door*) giving access to the bucket; while at the top of the suction pipe is the *clack piece*, also provided with a door, called the *clack door*, to give access to the clack. The *pump-rods* or *spears* are connected to the bucket by the *bucket-sword*, and work up and down, usually inside the delivery pipes. The suction pipe is joined to the clack piece; the lower end has a number of holes, instead of being open, as shown in fig. 145, to prevent large pieces of solid material from entering with the water, and is called the *windbore* or *snore*.

224. **Force Pumps.**—Force pumps are of two kinds, viz. those which pump water during only one stroke, termed *single-acting force pumps* (fig. 146), and those which pump it during both strokes, giving a continual flow, known as *double-acting force pumps* (fig. 147).

Contrasting the *single-acting force pump* with the bucket pump we see that it has a *plunger* or *ram* (P, fig. 146, or a *piston*, as shown in fig. 147), instead of a bucket, and a *casing* or *ram chamber*. The casing

is provided at the top, A, with a *gland* and *stuffing box* through which the plunger works up and down. There are *suction pipes* and a *suction valve* as in the bucket pump, and a *delivery valve*, DV, opening outwards, where the water passes from the casing into the *delivery pipes*.

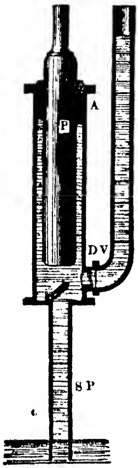


Fig. 146.—Single-acting Force Pump

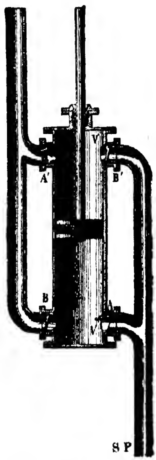


Fig. 147.—Double-acting Force Pump

Now on the *up-stroke* of the plunger the atmospheric pressure forces water up into the casing, the suction valve opening upwards, just as it forces it into the working barrel of the bucket pump. Then on the *down-stroke* of the plunger the suction valve closes and the water is forced through the delivery valve and up the delivery pipes. Thus, instead of *lifting* the water (as we have seen the bucket pump does), after it has been raised into the barrel or casing by the atmospheric pressure, the force pump *forces* it up to the surface or required level. The same rules apply in regard to the height of suction as in the case of the bucket pump.

The *double-acting force pump* has four valves, two suction (A, B′, fig. 147) and two delivery, B, A′. On the upstroke of the piston A, A′ are open and B, B′ closed,

the water in the casing above the piston being forced through A′ and up the delivery pipe, while at the same time the atmospheric pressure is forcing water up S P and through A, into the casing, for the next downstroke. On this commencing, A, A′ close and B, B′ open, the water below the piston being forced through B and up the delivery pipe, the atmospheric pressure forcing water up S P and through B′, into the casing, for the next upstroke.

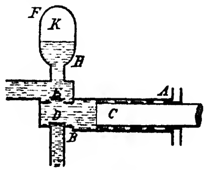


Fig 148

225. Air Vessel.—Force pumps are often provided with an *air vessel*, or chamber containing air (K, fig. 148), fitted to the delivery pipe. During the stroke of the piston the air in the chamber is compressed by the water, and when the piston stops to change the direction of its stroke, the air regains its former volume, thus keeping the water moving and preventing shocks to the pump consequent on the stoppage of the flow. Where there is an air vessel on a pump, means have to be taken to keep it supplied with air.

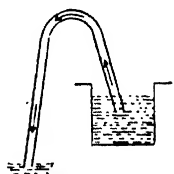


Fig 149 – Siphon

226. The Siphon.—The *siphon* (fig. 149) is an appliance for draining water from a *higher* to a *lower* level over an intervening height. It may be a bent tube, but as used in a mine consists of a number of pipes joined end to end. The end which dips into the water to be removed is called the *suction end*, and usually contains a light clack, which closes and prevents the water from running out when the siphon stops working. The other end is called the *delivery end*, and is fitted

with a plug or a tap, by which the flow of water can be regulated.

The siphon must be filled with water (or all the air pumped out) before it will act, the water, in a mine siphon, being introduced at the highest point by the aid of a pump or otherwise. On the delivery tap being opened the water runs out, tending to form a vacuum at the highest point, and the atmospheric pressure acting on the surface of the supply water forces water up the pipes and the flow continues.

Since the action of the siphon, then, depends on the atmospheric pressure, the vertical height of the elevation (or ridge) over which the water is conveyed obviously must not exceed the height of the water barometer (34 ft.), while in practice it must not be more than the "height of suction" in pumps. For efficient working the siphon must be well laid and the joints of the pipes air-tight. Where necessary, cocks are provided for the outlet of air, and to prevent air entering at the delivery end the latter is sometimes made to dip into water.

CHAPTER XXXIV

VENTILATING THE MINE

Vitiation of the Air in Mines—Distribution of the Air—Downcast and Upcast Shafts—Intake and Return Air—Doors—Stoppings.

227. **Vitiation of the Air in Mines.**—Ventilation means the constant exchange of pure for impure air. In a mine, as has been seen, the air is rendered impure in various ways: the gases given off by the strata; the breathing of persons and horses—this deprives the air

of oxygen and produces carbonic acid gas; the burning of lights, which has the same effect as the breathing of men and horses; the oxidation of the coal and timber, which also deprives the air of oxygen and produces carbonic acid gas; the gases resulting from blasting operations; and the dust produced in boring, &c. Accordingly, to keep the mine in a fit state for travelling and working in, a large amount of air must be continually passing through it (G.R. 1). In the present chapter the method of distributing the air in the mine will be dealt with; in the next chapter will be explained how the current is produced and how measured.

228. **Distribution of Air in the Mine. Downcast and Upcast Shafts. Intake and Return Air.**—In all places to be ventilated there must be at least one entrance for the pure air and one outlet for the impure air. As has been seen, it is compulsory in ordinary circumstances to have at least two shafts or openings to every mine. One of these openings or shafts is used as the entrance for the fresh air and the other as the outlet for the impure air. The shaft by which the fresh air enters the mine is called the *downcast shaft*, and that by which the impure air leaves, the *upcast shaft*. Usually the fresh air is called the *intake air* or *intake current*, and that which enters the upcast the *return air* or *return current*.

229. **Doors.**—When the pure air reaches the bottom of the downcast shaft it would naturally take the nearest way to the upcast shaft if not prevented. The nearest way would be through the "communication" or passage connecting the two shafts (§ 113), and this, therefore, must be stopped or closed in some way. A brick wall, called a *stopping*, might be built across it, but as the mine officials have frequently to pass from the one shaft bottom to the other, doors are used (figs. 150, 113).

These doors, termed *trapdoors* (or *ventilating doors*), are constructed to open *against* the current, that is, towards the intake current or in the direction of the fresh air. As will be seen in the next chapter, the intake air has a far greater pressure or force in it than the return air, and if the trapdoors were arranged to open towards the side on which the weaker current is, then they could never be kept shut, but would be blown open by the superior pressure in the fresh-air current. For this reason all trapdoors in a mine are arranged to open towards the intake current.

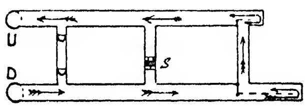


Fig 150.—Directing the Air Current

D, Downcast; U, upcast, doors; S, stopping, - - -, brattice. Arrows indicate direction of air current.

In the "communication", and in all important situations where trapdoors are required, at least two will be erected. If only one were used, then the air would rush through it when open, and the supply be cut off other places, perhaps involving great danger to the workmen. With two doors this is impossible, as one will be closed when the other is open, the distance between the doors being made great enough to permit of this. To guard against any chance of a door being left open they are built or "hung" so that they close of their own accord. But of course this must not be depended upon, and everyone passing through a trapdoor must *see* that it is perfectly closed. Any person carelessly leaving a trapdoor open which is intended to be shut is severely punished, and deserves to be.

Near the working faces doors would be inconvenient, and, as the air currents are feebler than nearer the shafts, brattice cloth or canvas (§ 235) is used instead. It is cut the full height and breadth of the road and nailed to a

crowntree. Where one thickness of cloth would be insufficient then two are used. Sometimes these substitutes for doors are called "screens", and sometimes double screens are used, with a short distance between them.

230. **Stoppings.**—Stoppings have already been mentioned in this chapter. Like doors and screens, their use is to guide the air along the course it is required to travel (figs. 150, 104). Doors or screens are employed at all places in the mine where it is necessary to pass from the intake to the return air. Where no such communication is required stoppings are used. On the main roads these are generally of brick, or rubbish, with a brick wall on the side next the intake, while nearer the faces wood is sometimes used. All stoppings are built across the full breadth and to the full height of the roadway. They require to be perfectly air-tight, so that no portion of the intake current may find its way through and escape to the upcast shaft without ever going near the working faces.

231. **Intake and Return.**—The fresh air, being unable to find a direct way to the upcast shaft (on account of the doors in the communication), must pass along the roadways leading from the downcast shaft through the workings, and back along the roadways leading to the upcast shaft—stoppings, doors, and screens being put in wherever required. And just as the fresh air, or ingoing current, is termed the "intake air", so the roads along which it travels are called *intakes* or *intake airways*, the roads or passages by which the return air passes to the upcast being termed *returns* or *return airways* (figs. 150, 113, 104). Thus we see the roadways on which the traffic of the mine is conducted serve also as the airways or channels for the passage of the air currents. The *main* intakes and returns are the roadways leading from the downcast and upcast shafts respectively. They are

called so because the whole of the air required for the ventilation of any district of the mine must pass along them.

232. **Splitting the Air.**—At one time it was the custom to ventilate the mine by one current of air only. The air after it left the downcast shaft was guided round the workings and then passed up the upcast shaft. All the impurities of the mine thus entered the one current, which accordingly became very foul. Besides, the method did not permit of an adequate supply of air being carried into the mine, and was very dangerous. It has therefore been abandoned in all important collieries, and a system called *splitting the air* adopted. In this method some of the air after it comes down the downcast shaft goes in one direction and some in another, forming distinct currents, or the one current *splits* into two or more currents (fig. 113). Each of the currents is a "split", and ventilates a separate district of the mine. Each, therefore, has its own intake and return, and is quite independent of the other splits.

Splitting the air can be understood to possess many advantages over the old method of passing the air through the mine. The quantity of air is increased and the atmosphere made fresher and purer. Also it is much safer, and the velocity of the air currents is greatly reduced. "Sub-splits" are also used, that is, a main current being divided into two or more smaller ones. To obtain the best results from splitting, certain rules require to be observed.

233. **Regulators.**—In splitting the air in a mine the workings in one ventilating district may be much farther from the shafts than those in another district, and just as the air would proceed direct from the downcast shaft to the upcast if not prevented, so the district nearer the shafts might receive more than its proper share of air.

Also one district may require more air than another. To ensure, therefore, that each receives its proper amount, *regulators* are, if necessary, used. These are simply ordinary doors or stoppings having openings fitted with sliding shutters. One is placed usually in the return airway of the district receiving too much air. By moving the shutter the size of the opening can be regulated until only the required amount of air is passing, hence the name "regulator". Regulators, however, are only used where absolutely necessary.

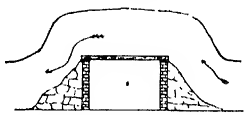


Fig. 151 —Ordinary Air Crossing

234. Air Crossings.—In the circulation of the air in mines it is sometimes necessary for the intake and return currents to cross each other (fig. 113). When that is the case the two currents must on no account become intermixed. The one current, therefore, must pass over or under the other, and for this purpose *air crossings* are employed (figs. 151, 152). These are really just air bridges. In most cases the return current is made to pass over the intake, the crossing being then called an "overcast". When the return current passes under the intake the term "undercast" is used.

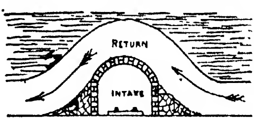


Fig. 152.—Arched Air Crossing

Air crossings are of various forms and degrees of strength. A type much used is shown in fig. 151. It consists of straight sidewalls of brick, on which tongued and grooved planks are laid transversely and plastered over with lime. Sometimes instead of the wooden top an arch of brick is built (fig. 152).

"Natural air crossings" are formed by driving the return through the solid strata above the intake. These are very strong but very expensive, and are rarely used. All air crossings must, of course, be perfectly air-tight.

235. **Brattice and Air Pipes.**—What *brattice* is we have already learnt (§ 174 and figs. 123, 150). It may be of *cloth, wood,* or *brick.* At the faces it is usually cloth. Props are set up, brattice deals nailed to the tops and bottoms of the props, close to the roof and floor, and the cloth secured to the deals. Thus "cloth brattice" is really a combination of wood and cloth. The latter requires to be very carefully fixed to prevent the air from escaping to the other side, and thus never reaching the face. Brick brattice is only used in very important situations, such as a long stone drift.

Instead of using brattice the air is sometimes taken into the face through pipes called *air pipes* or *air tubes.* These are usually constructed of sheet iron or wood.

CHAPTER XXXV

VENTILATING THE MINE—(*Continued*)

Production of Air Current—Furnace Ventilation—Fans—Natural Ventilation—Steam Jet and Waterfall—Measurement of the Pressure Producing Ventilation—Measuring the Air in the Mine.

236. **Production of Air Current.**—In all cases ventilation is the result of difference of pressure, the air travelling from the place of greater pressure to the place of less (§ 218). In a mine the place of greater pressure is the downcast shaft, and the place of lesser pressure the upcast shaft. The air therefore passes from the downcast shaft to the upcast, being guided wherever

required, as we have seen, in the course of its journey through the mine.

How the Difference of Pressure Necessary to Produce Ventilation is Obtained.—In both shafts there is the atmospheric pressure, and the difference of pressure necessary to produce ventilation is obtained by decreasing the atmospheric pressure in the upcast shaft or by adding to the atmospheric pressure in the downcast shaft. The first is the more general method. In regard to the *means* adopted for bringing about the difference of pressure, *furnaces* were employed in early times, and still are in some cases; in all new coal mines, however, machines called fans are installed on account of their greater safety and general superiority.

A current of air may also pass through a mine naturally, known as *natural ventilation*, or a difference of pressure be brought about by having a *steam jet* in the upcast shaft or a *waterfall* in the downcast shaft. Machines called *displacement machines* have also been used. When the ventilating current is made to pass through the mine by a machine, as a fan, &c., it is termed *mechanical ventilation.*

237. **Furnace Ventilation.**—In early times a fire-lamp was suspended in the upcast shaft, then furnaces came to be built near the bottom of the upcast, though in some shallow mines a firegrate was merely let into the brickwork of the shaft, and the miners as they ascended threw a piece of coal on to the fire.

Furnaces are constructed in such a way as to guard against the strata catching fire. On each side is an air space (fig. 153), and between the strata and the walling sand is packed. The return air passes over the fire and along the air passages at the sides. Where, however, the return air is so highly charged with inflammable gas that it would be dangerous to pass it over the fire,

then it must be sent into the upcast by another passage, called a *dumb drift* (G.R. 2 and fig. 154). In this case fresh air may have to be brought from the downcast to feed the furnace, which is thus less efficient.

When the furnace is large it is fired at the sides as well as from the front (fig. 153). In one furnace at present in operation the length of the firegrate is 60 ft. and its breadth 11 ft. The passage leading from a furnace to the upcast is usually called the *furnace drift*; it rises towards the shaft.

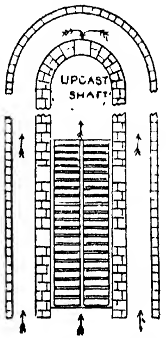


Fig. 153.—Plan of a Furnace

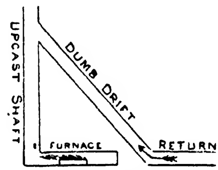


Fig. 154.—Showing Dumb Drift

A furnace reduces the atmospheric pressure in the upcast shaft by heating the air, thus expanding and making it lighter, volume for volume (§ 181). The heated air ascends the upcast shaft, and the colder and heavier sinks down the downcast and flows through the mine to be heated in its turn.

238. **Fans.**—Fans are of two kinds—*exhaust* and *compress* (also called *force* fans). An exhaust fan reduces the atmospheric pressure in the upcast shaft by making the air lighter; a force fan adds to the atmospheric pressure in the downcast by compressing the air, thus making it more dense or heavier.

In this country exhaust fans are generally employed.

The fan is placed a short distance away from the top of the upcast shaft, and is connected to it by a passage termed the *fan drift* (G.R. 3). The air passes from the upcast into the fan drift, thence into the fan (fig. 155), the mouth of the upcast being kept covered to prevent any air entering from the surface. The fan has a number of blades (fig 156), and at the centre, on one or both sides, an opening, termed the *inlet*, for the admission of the air from the fan drift. It is made to revolve,

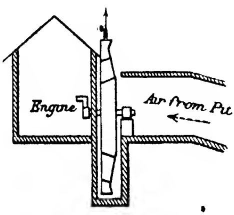


Fig. 155 —Waddle Fan

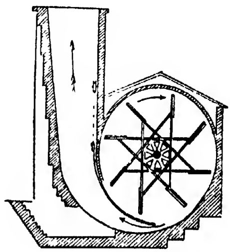


Fig. 156 —Guibal Fan

and the air entering at the centre is carried round between the blades and finally escapes at the circumference.

All bodies which are made to move in a circle have a tendency to fly off (in a straight line), just as in the case of a stone in a sling. This tendency is called "centrifugal force", and as the air moves out from the centre of the fan to the circumference because of its centrifugal force, fans are consequently known as *centrifugal ventilating machines*. The outward movement of the air from the centre of the fan to the circumference, and its flying off there, reduces the pressure at the centre of the fan and more air enters from the fan drift. This continues as long as the fan is working. The pressure being reduced, the upcast air expands and becomes lighter

and the colder and heavier air in the downcast sinks down and flows through the mine to the upcast.

There are many different makes of centrifugal fans. Most of these are enclosed in a casing (fig. 156). The air after it leaves the fan at the circumference passes into the atmosphere by means of an expanding chimney. This chimney, being of increasing area, gradually reduces the velocity of the air as the latter moves to the outlet. Fans such as these are called *enclosed fans,* examples of which are the *Guibal, Cockson, Walker, Schiele, Capell,* and *Sirocco* fans. The *Waddle* fan is constructed so that the air passes direct from the circumference into the atmosphere. It is therefore termed an *open-running fan.* The *Waddle, Guibal, Cockson,* and *Walker* are large fans running at comparatively slow speeds; the others named are small, quick-running fans (making a large number of revolutions per minute).

Running through the centre of the fan is the *shaft* by which it is revolved (figs. 155–6), the blades being connected to this. Some fans are driven direct, that is, the engine is coupled direct to the fan shaft, but high-speed fans are usually driven by ropes or a belt passing from a wheel on the engine to a pulley on the fan shaft. When a fan has one opening for the admission of the air it is termed a *single-inlet fan*; when it has one on each side, a *double-inlet fan.* Small fans are now often employed underground for ventilating stone drifts, &c.

239. **Natural Ventilation.**—If we have two shallow shafts at considerably different surface levels (fig. 157) a current of air may pass through the mine naturally. This is owing to the difference of temperature between the strata and the air on the surface. The temperature of the strata increases with the depth, and in winter the air in the deeper shaft will be warmer and less dense

than that in the shallower shaft. A current of air will therefore flow down the shallower shaft and up the deeper shaft. But in summer the air outside the mine will be at a higher temperature than the strata, and the air in the deeper shaft consequently colder and more dense than that in the shallower shaft. The former will, therefore, now be the downcast and the shallower shaft the upcast. Thus there is a reversal in the direction of the current. Again, if the external air is at the same temperature as the strata, no current will pass at all Thus natural ventilation cannot be depended upon, and *artificial ventilation* (fans and furnaces) is necessary.

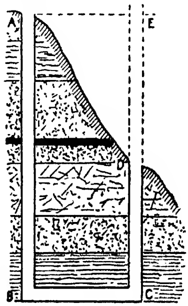


Fig. 157. -Natural Ventilation due to Difference of Surface Level

It should be observed that the temperature of the air in mines is increased by the burning of lights, and by the heat from men's bodies, &c., as well as by that of the strata. In a deep mine the temperature of the strata will usually be higher than that of the air outside the mine.

The *steam-jet* and *waterfall* are only used in modern coal mines in cases of emergency, as on a sudden stoppage of the fan. At some collieries, however, duplicate ventilating appliances are installed. It is interesting to note that when the steam-jet was introduced it was intended to supersede furnaces. It was, however, found to be less efficient, and did not come into general use.

240. **Measurement of the Pressure Producing Ventilation.**—The pressure, or rather difference of pressure, producing ventilation is measured by an instrument called a *water-gauge.* This consists of a U-shaped glass tube (fig. 158)

containing a little water, and having attached to it a movable scale marked in inches and tenths. One end of the tube is open to the intake air, and the other end to the return air, by a pipe fitted to this end being passed through a door separating intake and return. The greater pressure in the intake air depresses the water in the leg of the tube open to it, and consequently raises it in the other. The difference of level of the water in the legs is read by means of the scale.

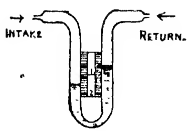


Fig 158.—Water-gauge

One inch difference of level is equal to a ventilating pressure of 5·2 lb. per square foot, 2 in. $= 2 \times 5{\cdot}2 = 10{\cdot}4$ lb. per square foot, and so on.

Usually the ventilating pressure is just spoken of as so many inches of water-gauge, or so many inches of W.G., without troubling to find the equivalent pressure in pounds per square foot. Improved forms of water-gauge[1] are now in use.

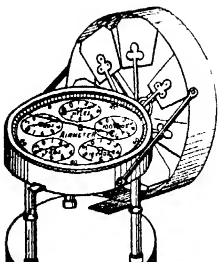


Fig 159.—Anemometer

241. **Measuring the Air in the Mine.**—The quantity of the air in the different splits is measured regularly (G.R. 1). For the purpose of ascertaining the *velocity* of the air current an instrument called an *anemometer* is used. This has a number of vanes (fig. 159) on which the air acts, driving them

[1] The action of the water-gauge is illustrated by means of a three-necked Woulfe's bottle. Into the middle neck of this is fitted a suitably bent glass tube containing a little coloured water, and into each of the other necks a short straight tube. The pressure inside the bottle is made less than that outside by gently sucking a piece of indiarubber tubing attached to one of the upright pieces.

round as the wind does the sails of a windmill. Wheel-work is set in motion which in turn actuates pointers on dials, the last-mentioned recording the velocity of the air current. The velocity of the current in feet per minute multiplied by the sectional area in square feet of the airway at the point where the observation is made gives the number of cubic feet passing in one minute.

The instrument, suspended at the end of a stick, is held in the current for a certain time. With some anemometers a watch is necessary, others are self-timing or provided with a sandglass. The air moves fastest at the centre of the roadway, the resistance being less there than at the sides, and to obtain the correct velocity the average of readings in different positions is taken or the instrument moved slowly over the cross section of the passage. A part of the airway of uniform section, easy to measure, is chosen, and the operator has to keep in one position as much as possible. His body, it will be seen, reduces the area of the passage for the air. In ordinary anemometers an allowance has to be made for the friction of the wheelwork. If provided with a stop, the instrument should not be put "into gear" until the vanes are revolving at full speed. Anemometers are very delicate instruments and require to be handled carefully and tested at intervals.

CHAPTER XXXVI

LIGHTING

Methods of Lighting—Safety Lamps

242. **Methods of Lighting.**—Some sort of artificial light is necessary to enable the miners to see to do their work and to travel about in the mine. The *pit bottom*, being

usually a very busy place, requires to be well lit up. The lights are stationary, and may take the form of large paraffin lamps, of ordinary illuminating gas brought from the surface in pipes, of acetylene gas, or of incandescent electric lamps. On the *roads* lamps are carried. Electric lighting is now common at large collieries, and glow lamps are sometimes fixed at important places in the main haulage roads as well as at the shaft bottom. At the *faces* lamps or, sometimes, candles are used.

In some mines *open* or *naked* lights are used (*i.e.* candles and the small lamps which hook to the front of the cap), and in others only *safety lamps* (see G.R. 8 (*a*)). In others again, and even in the same ventilating district, both naked lights and safety lamps are employed, the former where it is considered safe and the latter where unsafe. This is sometimes called *mixed lighting*, and where in operation open lights must not, of course, on any account be carried into the part of the mine where safety lamps are in use (G.R. 8).

243. Safety Lamps.—A safety lamp is a lamp constructed in such a way as, under certain conditions, not to ignite the explosive atmosphere by which it may happen to be surrounded. The words "under certain conditions" must be noticed. It will be seen from what follows that all so-called safety lamps are safe only within certain limits. They are, it may be said, like safety bicyles, not absolutely safe. The first safety lamps in a practical form were those invented by Sir Humphry Davy, Dr. Clanny, and George Stephenson, and known respectively as the *Davy*, *Clanny*, and *Stephenson* (or "Geordie") lamps (figs. 160–2). Previous to the introduction of these lamps there were no proper means for guarding against ignitions of mixtures of firedamp and air or of detecting the presence of firedamp. In 1760 Spedding's *steel mill* was devised.

This consisted of a steel wheel which a boy by turning a handle caused to rotate rapidly against a piece of flint. So long as the boy kept the wheel revolving sparks were produced, the miner having to do his work by the faint light thus given. Spedding's mill was soon shown to be unsafe by the explosions which followed its use, but nevertheless continued to be employed for many years.

About the beginning of the last century so great was the number of explosions occurring in coal mines that public attention was called to the matter, and earnest endeavours were made to devise some safe means of lighting. The result was the invention of the lamps already named.

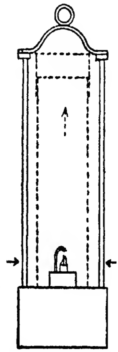


Fig 160.—Davy Lamp

Dotted lines indicate wire gauze; double lines at side the poles or standards; bottom part is the oil vessel; arrows show direction of air

The Davy Lamp (fig. 160).—All safety lamps are provided with locks of some kind, and after unlocking we find that the base or oil vessel unscrews from the upper part or frame. On examining the oil vessel—made of brass and cylindrical in shape—we see it is provided with a burner, and, for trimming the wick, a pricker which passes up a little tube running through the oil vessel. The wick can thus be adjusted without opening the lamp. At the base of the frame is a brass ring which screws to the oil vessel, and at the top is another ring which is connected to the bottom ring by three iron rods or uprights; these uprights serve also to protect the gauze cylinder held within the frame. Attached to the upper ring is a metal roof or cap, and fixed to this is the loop or handle by which the lamp is carried. The gauze cylinder is about 1½ in. in diameter and 6 or 7 in. long.

It is constructed of iron wires about $\frac{1}{50}$ in. diameter. The wires run vertically and horizontally, crossing each other. There are at least 28 apertures to the lineal inch, giving 784 to each square inch. The air to feed the flame, or the "feed-air" as it is often termed, enters by the apertures at the base of the gauze, and the products of combustion pass out by those at the top. As the effect of the heat is therefore greatest on the upper part of the gauze, the latter is provided with a cap, that is, it is made double.

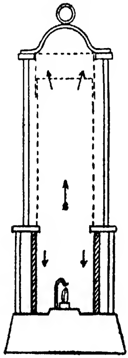


Fig. 161.—Clanny Lamp
Shaded oblique lines indicate glass

The Davy lamp, on being tested, will be found to give a poor light. This is one of its defects; another is that it is unsafe in a current of air moving at even a low velocity, the flame being blown through the gauze when this is as little as 6 ft. per second, or less if the lamp is being carried against the current. This will be better understood after learning the principle of the safety lamp (§ 244).

Clanny Lamp (fig. 161).—On examining a Clanny lamp we see that it has a glass cylinder round the flame, rods protecting this, and an additional ring. Otherwise it is similar to the Davy lamp. The glass cylinder, made air-tight at top and bottom by the aid of asbestos washers, takes the place of the lower part of the gauze in the latter lamp. The feed-air enters above the glass, and the products of combustion escape as in the Davy lamp. On making a test we find that, owing to the presence of the glass cylinder, the lamp gives a little better light than the Davy. It is also a little safer in a current of air, the flame being passed through the gauze when the velocity is about

8 ft. per second. The light would be better, but part of the products of combustion mix with the fresh air and are carried down on to the flame.

Stephenson Lamp (fig. 162).—The figure and description will be sufficient for this lamp, as it is not now used much, if at all, in mines The gauze is larger in diameter than that of the Davy or Clanny. Inside of it, reaching nearly to the top, is a glass cylinder. Surmounting the latter is a perforated copper cap. The feed-air passes in through perforations in a ring at the base of the lamp, and the products of combustion up through the holes in the copper cap, thence out through the gauze. The glass cylinder renders the lamp safer in a higher velocity of air current than the Davy or Clanny, but the lighting power is reduced. In the mine the air holes become choked with dust. As originally made, Stephenson did not use a gauze, but a perforated sheet-iron shield. The gauze was invented by Sir Humphry Davy, and was afterwards adopted by both Dr. Clanny and George Stephenson.

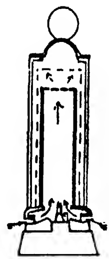


Fig 162.—Stephenson Lamp

244. We come now to the consideration of *how the safety lamp prevents explosions of firedamp and air.* It is by means of the gauze, but to understand how this acts we must bear in mind what a *conductor of heat* is (§ 182), and learn what is meant by the *ignition-point* of a substance.

The ignition-point of a substance is simply the temperature to which the substance must be raised before it will ignite. Every combustible substance has its own point of ignition, and unless the heat applied is sufficient to raise the temperature of the substance to this point then it will not ignite, The following experiments illus-

trate this, also the power of iron wire as a conductor of heat.

Place an iron-wire gauze over a jet of burning gas (fig. 163 A). The flame does not pass through the gauze, yet if we apply a lighted taper to the upper side of the latter, flame results, showing that gas goes through the gauze. Now flame is just burning gas, and what happens is this. The gauze, being a good conductor, takes away the heat so quickly from the burning gas, that the temperature is lowered below the ignition

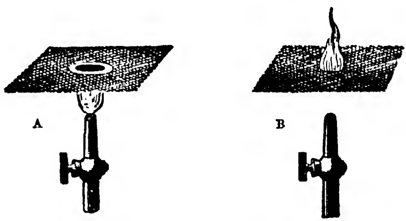


Fig. 163.—Action of Wire Gauze on Flame

point, and so no flame passes through the gauze. When we apply the taper to the upper side of the gauze, we raise the temperature once more to the ignition-point, and so we have flame both above and below the gauze.

Now vary the experiment by lighting the gas first above the gauze (fig. 163 B). The flame does not pass down through the gauze for the same reason as before. The gauze conducts away the heat so quickly that the temperature on the under side is not sufficient for the gas to ignite. In both cases, however—and it is of the utmost importance to note this—if we allow the gas to burn long enough, then the gauze becomes heated just as does a wire held in the fire. It is then no longer

able to reduce the temperature of the burning gas, and the flame passes through.

Now these experiments illustrate the principle of the safety lamp. The mixture of firedamp and air enters the lamp, is ignited at the wick flame, and explodes, or the firedamp burns inside the gauze; but owing to the action of the latter in conducting away the heat, the flame does not pass through. But if, as has been seen, the gauze, or any part of it, is allowed to become heated, then the flame will pass through. The same may happen in the case of an explosion within the lamp.

245. **Modern Lamps.**—We may now turn our attention to present-day types of safety lamps. There are many different lamps in the market, but the reader will find on examining such as are provided for him in his class that they vary only in details of construction, modern workers on the safety lamp retaining the gauze and other features, and aiming at making the lamp safer, of higher illuminating power, and improving it generally.

The modifications of each patentee, then, are to be found in the particular make of lamp, and all modern lamps should be compared with the old Clanny and with each other. As the result of experiments, especially those of a Frenchman, M. Marsaut, much has been learnt in reference to points of construction, which affect the safety of the lamp in regard to the communication of the flame to the outside air when an explosion occurs within the lamp. One great general improvement is the use of a metal shield or bonnet to surround the gauze, rendering the lamp safer in a rapid air current. This addition was made necessary by the higher velocities of air currents in modern mines (G.R. 9). The manner of admitting the air to the flame and allowing the products of combustion to escape in each lamp should be observed.

Improvements have also been made in burners, method of locking, &c.

Sometimes a Davy lamp is enclosed in a tin can, or case, provided with a window, and is then termed a *Tin Can Davy*. This adds greatly to the safety of the lamp in a rapid air current, but the light is not improved. The air enters through holes at the base of the can. A *Bonneted Clanny* is a Clanny lamp fitted with a shield.

Other lamps are the Mueseler, Marsaut, Deflector, Hepplewhite-Gray, and Wolf. They can only be briefly referred to here.

Mueseler Lamp.—This lamp (fig. 164) is similar to the Clanny, but is provided with a conical metal chimney, up through which the products of combustion ascend. This chimney creates a draught and improves the combustion of the lamp. It is held in position by a horizontal gauze diaphragm. The feed-air passes in through holes at the base of the shield, through the gauze, then through the gauze diaphragm. Sometimes the lamp is used without a shield, and is then, of course, less safe in a rapid air current. When tilted the products of combustion mix with the inlet air, and the flame is extinguished.

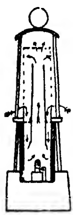


Fig 164 — Mueseler Lamp

Fig 165.— Marsaut Lamp

Marsaut Lamp.—This lamp (fig. 165) is also similar to the Clanny. There are, however, two, sometimes three, gauzes. These are slightly conical in shape. They are close together at the foot, but gradually diverge. The number and arrangement of gauzes reduce the internal volume of the lamp (or space in which an explosion can take place) and add to the gauze surface. This lamp is much used.

The *Deflector* lamp is like the Marsaut, but has an arrangement for guiding or "deflecting" the inlet air.

In the *Ashworth-Heppelwhite-Gray* lamp (fig. 166) the glass is of a conical form, and on the top of it is a short gauze, also conical in shape. The feed-air passes down through tubes which are used instead of solid standards, entering at the top. Air can also be admitted, if required, by openings, provided with sliding shutters, in two of the tubes near the bottom. The air passes from the tubes into a small circular chamber above the oil vessel, thence through a gauze to the flame. The products of combustion escape through holes at the top of the lamp. Owing to the shape of the glass this lamp throws a light on to the roof, and the air being admitted at the top renders it suitable for gas-testing.

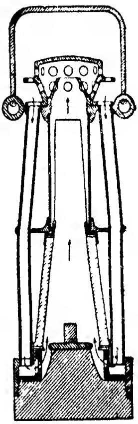


Fig. 166. – Ashworth-Hepplewhite-Gray Lamp

Wolf Lamp.—This is a Clanny type of lamp, but with the air entering from below the flame. It gives a good light and is provided with an arrangemant by which it can be relit, should the flame be extinguished, without having to open the lamp. Usually when a lamp is extinguished it is taken to the lamp station (G.R. 10, 11), but with a relighting apparatus, such as is provided in the Wolf lamp, this is unnecessary. There are, however, very strong objections to relighting lamps in the workings, on account of the danger of an explosion.

Electrically-ignited Safety Lamps—Electric Lamps.—At some collieries the safety lamps are fitted with an arrangement to enable them to be lighted instantly by

means of an electric spark or incandescent wire. Such lamps can be relit at a lamp station without being opened, but here again caution is necessary, as the lamp may have been damaged, and it is therefore maintained that every safety lamp which has been extinguished in the workings ought to be thoroughly examined before being again put into use. Small portable *electric lamps* are also in use at some mines. One such lamp is the "Sussman". An electric lamp gives no indication of the presence of gas.

246. **Cleaning, Examining, &c., of Safety Lamps.**— When the shift is finished the lamps are taken to the lamp room, and are there unlocked, the oil vessels unscrewed, the various parts separated and examined, and the gauzes and glasses thoroughly cleaned. Sometimes the cleaning is done by hand and sometimes, where the number of lamps is large, by a machine constructed for the purpose. The oil vessels have also to be charged, and such lamps as require them provided with new wicks.

In *examining* the parts of a safety lamp great care is necessary. The danger of the enlargement of the mesh of the gauze from any cause, of the defective condition generally of the gauze, or of the glass being cracked, must be understood. The different parts of the lamp must be fitted properly together, the junction of the glass with the rings being made perfectly air-tight. As will be seen from the *Special Rules*, every safety lamp must be examined immediately before being taken into the workings, to ascertain whether it is "in safe working order and securely locked in terms of General Rule 10". Usually the junction of the glass with the rings is tested by blowing on to the glass, top and bottom, with a small tube; but sometimes the lamps are subjected to an actual gas test in a special

Fig. 167.—Testing for Firedamp

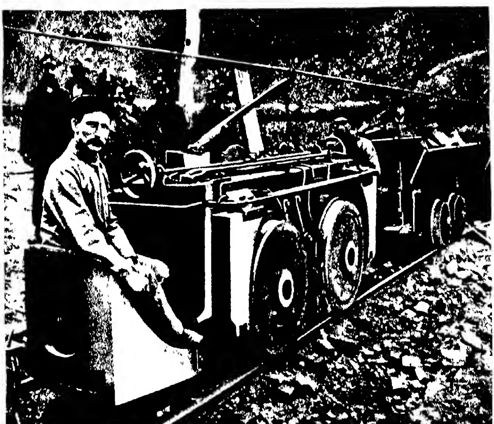


Fig. 172 A.—Electric Locomotive (Morgan-Gardner Electric Co.)

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testing apparatus before being handed to the workmen. For securing the lamp, as required by the rules, different kinds of locks are in use, as the *screw*, *lead rivet*, and *magnetic* locks. Some lamps are fitted with an appliance by which the light is extinguished should an attempt be made to open the lamp.

247. **Using the Safety Lamp.**—From what we have learnt in connection with "safety" lamps it is plain that (§ 243) they are far from being absolutely safe, and that to render them as safe as possible the utmost care is necessary in their use. In the *Special Rules* directions are given for the examination and use of lamps, and anyone disregarding these requirements risks not only his own life but the lives of his fellow-workmen. It is evident that the gauze must not be allowed to become hot through firedamp continuing to burn within the lamp, the lamp must not be subjected to too rapid an air current, no attempt must be made to blow the flame out, and the lamp must not be swung or jerked, or raised recklessly above the person's head. A person who has learnt about the safety lamp knows that it must not be tampered with, that he must take care of it, and place it so that it will not be injured by any tool in working. The lamp must be frequently examined. The special rules give instructions how to proceed should the appearance of gas be detected, or should an accident happen to the lamp.

248. **Detecting the Presence of Firedamp.**—By tests with simple apparatus we can become familiar with the action of firedamp on the flame of a safety lamp. To acquire the knowledge necessary for a fireman, however, more elaborate means are required, as well as practice in the mine.

If the mixture of firedamp and air is explosive an explosion takes place within the lamp (§ 244), and the

flame may be extinguished by the products of combustion. If the mixture is not explosive the firedamp in contact with the flame burns (§ 244), and there is formed over the flame a blue cap the size, shape, and intensity of which vary with the percentage of firedamp in the air.

In testing for firedamp, the usual way is to raise the lamp steadily, keeping it vertical, and shading the flame from the eyes with the hand (the flame must not be too large). If there is much firedamp present the flame lengthens (termed "drawing"). If no elongation takes place the lamp is steadily lowered and the wick pulled down until the flame is *non-luminous*, care being taken, however, not to extinguish it. Then the lamp is again steadily raised, and a "cap" may be seen.

Recently enquiries into the methods of examining for firedamp in coal mines were made by experts on behalf of the Royal Commission on Mines,[1] and from the result of these attention has been drawn to the necessity of using a reduced flame when testing. A luminous flame "masks" or prevents the cap from being seen, and failure to test with a small flame may result in the non-detection of a percentage of gas bordering on the explosive. The smallest amount of gas that can be detected with a non-luminous flame depends on the lamp, its condition, the oil, &c., used, as well as the skill of the observer; but it is maintained that every skilled person should be able to detect 2 per cent. Since the foregoing was written it has been found that small percentages of firedamp may be detected, without the necessity for lowering the lamp flame, by a piece of asbestos-sheeting steeped in a strong solution of carbonate of soda being placed in the flame. This changes the colour of the cap from blue to yellow when it becomes visible.[2]

[1] Blue book: Reports by Dr. Cadman and E. B. Whalley, 1909.
[2] *Trans. Inst. Min. Eng.*, xxxviii, 259, and xxxix, 13.

Firedamp Indicators—These are intended to be used in the detection of very small percentages of firedamp. In one a hydrogen flame is used, in another an alcohol flame.

CHAPTER XXXVII

BRINGING THE COAL TO THE SHAFT BOTTOM

Mine Wagons—Rails, Sleepers, &c.—Conveying the Tubs to and from the Workings.

249. **Mine Wagons.**—In the introductory chapter we saw as to the early methods of removing the coal from the working places. For carrying the coal little wagons, called *hutches*, *tubs*, or *trams*, are now used (fig. 168). These are simply large boxes, generally rectangular in shape, fitted with wheels. They require to be very strongly constructed. The box part or body is usually of wood, strengthened with iron, but is sometimes made wholly of iron or steel. The axles and wheels are generally of steel. When run in trains they are joined together by means of couplings. The couplings are connected to a metal bar, termed a "draw-bar", fixed

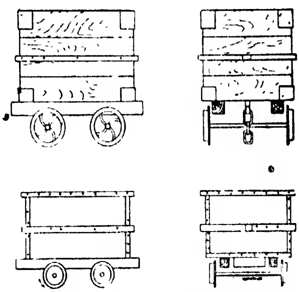


Fig. 168.—Side and End Views of Wood and Iron Tubs

to the bottom of each tub. Other names, beside "train", for a number of tubs running coupled together are *set*, *rake*, and *gang*. Thus we speak of a "set of tubs", a "rake of tubs", &c.

In designing a tub, carrying capacity, strength, lightness, and ease of running are all considered; and in order to reduce the force necessary to propel the tubs, and to prevent wear, the bearings are regularly oiled or greased, sometimes by an automatic arrangement which, as the tub passes over it, lubricates the axle.

The load which a tub carries varies greatly, and depends on local circumstances, as, for instance, the thickness of the seam. In some cases the weight of coal is as little as 6 cwt. and in others over a ton.

250. **Rails, Sleepers, &c.**—The rails on which the tubs run are now usually of steel, and the sleepers to which the rails are fixed of wood, though sometimes iron or steel sleepers are used.

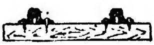


Fig 169.—Bridge Rails

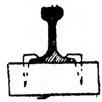


Fig 170—T-Rails

Figs. 169, 170 show two forms of rails used in mines. On the face roads the traffic is not great, and light rails are sufficient. They are in short lengths, 3 to 6 ft., so that they can be easily handled both in laying down and removing them. On the main or permanent roads longer lengths, 12 to 18 ft., are employed, in order to give fewer joints, and, as much greater strength is required, the weight of the rails per yard of length is necessarily considerably more than on the side roads. Sometimes on the face roads flat iron bars fixed into notches made in the sleepers are used, and sometimes on the main roads double-headed rails like those in use on surface railways, but lighter, are employed.

A common distance between the rails, or the *gauge* as

it is termed, is 2 ft., but this varies. The sleepers are from about 3 to 6 ft. apart. Where these are of wood, bridge or T-rails are secured to them by means of nails or spikes with hook heads, termed "dogs" (see figures). Sometimes in joining the T-rails "fishplates" and bolts are used. The thickness and breadth of the sleepers vary with the weight of the rail used. At the places on main roads where the hutches pass into the side or branch roads, *points*, *crossings*, &c., are necessary. Lines of rails on main roads require to be well and strongly laid.

251. **Conveying the Tubs to and from the Workings.**—The general name for the conveyance of the empty tubs from the shaft bottom to the workings, and of the loaded ones to the shaft bottom, is *haulage*, a qualifying word being used according to the means adopted for propelling the hutches. Thus we have *manual haulage*, in which the tubs are moved by men and boys; *horse haulage*, in which the work is done by horses, ponies, and mules; *self-acting* or *gravitation haulage*, in which it is done by gravity; and *mechanical* or *engine haulage*, in which an engine supplies the motive power. All these systems may be found in operation in the same mine. The roads are termed *haulage roads*, those on which the tubs are moved by engine power being often called *engine planes*. The terms *haulage plane* and *underground plane* are also used.

Manual Haulage.—Haulage by men and boys is chiefly done on the face roads, conveying the tubs between the faces and main roads, or *sidings* or *lyes*, whence they are transported to the shaft bottom by horses or other means. Men and boys engaged specially for this work are termed *drawers*, *putters*, or *trammers*. We shall see presently how in inclined seams the work of the drawer is sometimes assisted by gravity. A tub

is, of course, more easily pushed along a level road than up an incline, and in going downhill the tub may have to be held back or spragged. On the level road the resistance is that of *friction* only; going uphill there are both friction and gravity to be overcome; while downhill friction is tending to stop the tub and the pull of gravity to make it run away. If the latter is greater than the resistance of friction, then the tub must be held back or spragged. "Sidings" or "lyes", also called "stations", are places made at convenient distances from the faces for the collection and distribution of the tubs. They have two lines of rails, one for the full tubs and one for the empties.

Horse Haulage.—In some cases ponies, sometimes termed "face ponies", are employed in taking out hutches to the lyes or sidings. Horses are also used on the main roads of some mines. In mines where horses are employed stables are made to which the animals are taken when their work is finished. Horses in mines ought to be very kindly treated (see also G.R. 17). Sometimes it is possible to lighten the work of a horse, as by making it walk on the level or downhill where the load has to be hauled up a steep incline.

Gravitation Haulage.—The force of gravity can be utilized as a means for moving tubs from one place to another only in seams with a sufficiently high inclination, where the coals have to be conveyed downhill. The principle is that the loaded tubs running downhill pull up the empty tubs.

Self-acting Inclines (also called *Jigs* and *Cousies*, the latter name in Scotland).—The term "incline" is applied generally to an inclined road, and a "self-acting incline" means an incline of such a gradient that the tubs "self-act" (that is, no horse or other external source of power is required to propel them).

At the top of a self-acting incline a drum or pulley (fig. 171) is fixed. One end of a steel-wire rope, which passes round the sheave of the pulley, is connected to a train of empty hutches at the foot of the incline and the other end to a train of loaded hutches at the top. When all is ready the trains are started, the loaded gang going downhill hauling the empty rake up.

Two lines of rails, one for the full set and one for the empty, may be used; but sometimes the road has to be narrow, and then other arrangements require to be adopted. Sometimes three, and even two, rails are used, except at the place, termed the *pass-bye* or *meetings*, where the rakes pass each other. A brake is attached to the drum or pulley for the purpose of regulating the speed, and to prevent the full hutches running away while the sets are being made up appliances called *blocks* or *stops* are fixed across the rails at the top of the incline. Also, to prevent the rope from rubbing on the ground when the sets are running, small pulleys of a suitable shape are fixed at intervals in the middle of the tramway or where necessary. Pulleys are used for this purpose in all systems of haulage in which ropes are employed.

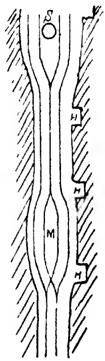


Fig. 171.—Self-acting Incline

S, Sheave; M, meetings or pass-bye; H, refuge- or man-hole (G.R. 14-16)

Other Forms of Self-acting Haulage.—Sometimes a chain is employed on self-acting inclines instead of a rope, and sometimes where roads branch off at intervals up the incline a system is used in which single tubs can be lowered from each road as required, each full tub hauling up an empty tub.

Very often where drawers have to work on an inclined

road a pulley is secured to a strong prop, which must be very firmly fixed (fig. 172). One end of the rope or chain which passes round the pulley is connected to a loaded wagon, called a *bogie*, *balance wagon*, or *cuddy*, which runs on a separate line of rails of narrow gauge. The loaded hutch is connected to the rope at the top of the incline, and in descending draws up the bogie. Then the empty hutch is hooked on to the rope at the bottom of the incline and drawn up by the bogie. This form of incline is termed a *jig brow* or *cuddy brae*.

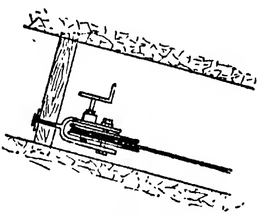


Fig 172.—Pulley at Top of Incline

On inclines where the gradient exceeds about 30 degrees the coals would fall out of tubs running on rails in the ordinary way, and to prevent this the tubs have to be conveyed on carriages provided with a horizontal platform.

252. **Engine Haulage.**—The different systems of engine haulage are (1) single rope or direct-acting haulage; (2) main- and tail-rope haulage; (3) endless-rope haulage; (4) endless-chain haulage. These are worked by stationary engines. (5) Electric locomotives. These are largely used in America; compressed-air locomotives are also common.

For haulage on the main roads steam engines situated either on the surface or near the shaft bottom are very often employed. In the former case the haulage ropes pass down the shaft, and in the latter steam pipes require to be fixed in the shaft, extending from the boilers on the surface to the engine underground. Electrically-driven engines are also used. Haulage on the main roads is known as the *main haulage*,

and that by men and boys, &c., bringing out the tubs to the sidings to feed the main haulage as *secondary haulage.* Engines worked by electricity and compressed air are also employed in secondary haulage.

Single-rope Haulage.—In this system of haulage the hutches run in rakes. A single line of rails is used. The empty rake runs downhill by gravity, hauling the rope after it. The drum, which can be put into or out of gear as required, is out of gear on the inbye journey of the tubs. At the siding the rope is transferred to the full rake, the engineman at the same time throwing the drum into gear. The signal is given, and the full

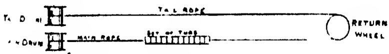


Fig 173.—Main- and Tail-rope Haulage

rake drawn up the incline by the engine. It will be seen that the gradient must be sufficient to permit of the hutches running downhill and drawing with them the rope. The rakes run at a high speed.

The Main- and Tail-rope System.—In this system the hutches also run in rakes (fig. 173). It is the single-rope system with the addition of a tail rope. The road is either level or the gradient such that the empty rake is not able to run into the workings and pull with it the rope. The tail rope is therefore used for the purpose of hauling both rake and main rope inbye. Two drums are used, one for each rope, and they can be thrown into or out of gear as required. The tail rope passes along the engine plane, round a pulley at the end, and back to the rake. The main rope is connected to the other end of the rake, and when the tail-rope drum is put into gear and the main-rope drum out of gear the engine draws rake and main rope into workings. When the full rake

is being drawn outbye the main-rope drum is in gear and the tail-rope drum out of gear. This is also a high-speed system of haulage. For detaching the main rope from the rake at the shaft bottom an automatic arrangement is sometimes used.

Endless-rope System of Haulage.—In the system of

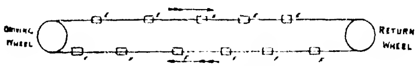
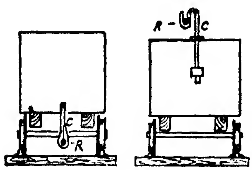


Fig 174 —Endless-rope Haulage

E, Empty tubs, F, full tubs

endless-rope haulage, which is generally adopted, two lines of rails are used, one for the full hutches and the other for the empties (fig. 174). This necessitates a wide road. At one end of the road is the driving pulley worked by the engine, and at the other a return pulley. The rope passes round these, and thus makes a complete circuit. It travels usually either under or over the tubs. For attaching the tubs to it *clips* of a suitable form are used (figs. 175, 176). Sometimes chains, called *lashing chains*, are employed for this purpose. The hutches are connected singly, at intervals of a certain number



Figs 175, 176 —Under rope and Over-rope Haulage

R, Rope, C, clip

of yards, as shown in fig. 174, or two, three, or four are coupled together, and the one in front connected to the rope. The speed is slow, about 1 to 4 miles per hour, and the road may be level or inclined. The rope requires to be kept tight, and for this purpose a *tension arrangement* is necessary (fig. 177). Branch haulages

are worked off the main haulage by means of appliances called *clutches*.

In another system of endless-rope haulage, in which a single line of rails with pass-byes is used, the hutches are run in sets and coupled to a bogie which is provided with an appliance for gripping the rope. An attendant travels with each rake.

Endless-chain System.—In this system a chain is used instead of a rope. Otherwise it is similar to the endless-rope system, with the rope over the tubs.

253. **Working Curves.**—Where there are curves on main haulage roads special means are necessary for guiding the rope and tubs round these.

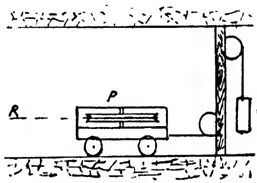


Fig 177—Tightening Arrangement for Endless rope Haulage

P, Pulley mounted on tension carriage, R, endless rope passing round pulley; W, weight to keep R tight

Safety Appliances.—For the purpose of safety and for preventing damage various safety appliances, suitable to the form of haulage, are in use, as "blocks", for example (self-acting inclines).

Signalling.—On main haulage roads electric signalling is adopted, the current being supplied by a battery. Two iron wires connected to the battery and bell in the engine house are carried along the road on insulators. The wires are about 6 or 8 in. apart, and the signals are made by pressing them together or connecting them with an iron rod.

CHAPTER XXXVIII

RAISING THE COAL TO THE SURFACE

General Arrangement—Winding Engines—Drums—Headgear and Pulleys—Ropes—Rope Cappings and Cage Chains—The Cages—Signalling—Guides—Detaching Hooks and Safety Cages—Counterbalancing—Special Methods of Winding.

254. **General Arrangement.**—In the old systems of raising the coal to the surface, ladders (fig. 2), windlasses (fig. 83), and a machine called a *horse whim* or *gin* (fig. 178) were used At the present time *steam engines* are generally employed. These work a *drum* (fig. 179) to which two *steel-wire ropes* are attached. The ropes pass over two large *pulleys*, fixed at the top of an erection, termed the *headgear*, which is built over the shaft (fig. 191). Each rope is connected to a *cage*, or framework, in which the men descend and ascend the shaft, and in which the tubs are raised and lowered, one cage being always at the surface while the other is at the shaft bottom, the two thus passing each other in the shaft.

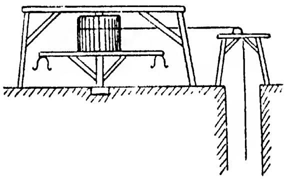


Fig 178 —Horse Whim or Gin

255. **Winding Engines.**—The general name for raising the men and material to the surface is *winding*, and the engines are called "winding engines", just as those employed for haulage purposes are termed "haulage engines". Similarly the drum is referred to as the "winding drum" and the ropes as the "winding ropes". Generally *steam* engines are employed, though *electric*

engines have been tried, and are used at some places on the Continent. Both *vertical* and *horizontal* steam engines are in use, but the latter form is the one generally adopted. A vertical engine has its steam cylinder placed in an upright position; in a horizontal engine the steam cylinder rests horizontally on its seat. Fig. 179 shows the general arrangement of horizontal engines and drum. Passing through the centre of the drum is the *drum shaft*, to each end of which there is connected a *crank*. The *connecting rod* connects the crank to the end of the piston rod or *cross-head* (§ 183). Two engines are generally used, because winding might be stopped when the crank was on the "dead centre", that is, in a straight line with the piston and connecting rod (this happening twice in each revolution of the drum), and a single engine has then no power to revolve the drum. With two engines the cranks are fixed at right angles to each other, thus there can never be any "sticking on the dead centre".

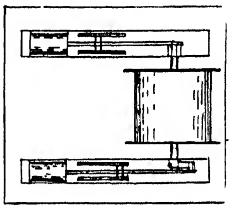
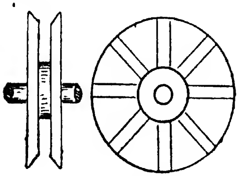


Fig 179 -Horizontal Winding Engine

Engines placed as shown in the figure are termed "coupled engines", and also "direct-acting engines", because they are connected direct to the drum shaft, that is, no gearing wheels coming in between.

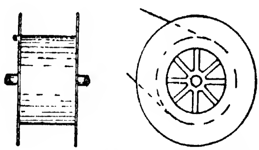
Winding engines require to be very powerful and strongly built. They do not work continuously like a locomotive or marine engine, but have to start the load from rest, have it going at mid wind at a very high speed, and then bring it gradually to rest again—all in less than a minute. Adequate brakes worked by foot

and steam are provided for stopping the engine, and sometimes automatic appliances are used, which cut off the steam and apply the brakes in case of too rapid running near the end of the wind. By means of an apparatus called an *indicator*, which is worked off the drum shaft, the engineman can always tell the position of the cages in the shaft, and thus knows when to check the speed or shut off the steam and bring the engines to rest. As a further precaution the indicator strikes a bell as the cage approaches the surface.



Figs. 180, 181 —Front and Side Views of Drum for Flat Ropes

256. **Drums.** — Different forms of drums are used. Formerly flat ropes were generally employed in winding, and the drum (figs. 180-1) consisted of a small barrel or cylinder on which the rope coiled. Fixed to each side were arms or projections to guide the rope on to the barrel and also prevent it from slipping off.



Figs. 182, 183.—Front and Side Views of Cylindrical Drum for Round Ropes

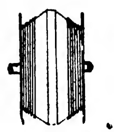


Fig 184 —Spiral Drum for equalizing Load on Engine

At the present time round winding ropes are mostly used, and to suit these larger and wider drums are required. Two forms are in use—the *cylindrical* (figs. 182-3) and the *spiral* (fig. 184). A third form, termed the *conical drum*, has also been tried. In both present-

day types the one drum serves for both ropes, the rope attached to the descending cage uncoiling from, as that attached to the ascending cage coils on to, the drum. One of the ropes (the "over rope") therefore passes from the top of the drum to its pulley, and the other (the "under rope") from under the drum to its pulley.

On a cylindrical drum the successive coils of the rope lie side by side, not on the top of each other as in the case of the flat-rope drum. The part on which the ropes coil is known as the drum "lagging". It is of wood or iron, and is secured to iron or steel rings, one at each side of the drum, and sometimes one at the centre, the rings being connected to the shaft. A flange is provided at each side. Some of these drums are very large, being in some instances over 20 ft. diameter.

Spiral drums resemble two cones placed base to base. The ropes coil on the tapered parts, which are provided with grooves for the reception of the coils. Conical drums were similar in construction, but had no grooves, and the ropes were liable to slip.

With a cylindrical drum all the surface of the drum on which the rope coils is of the same diameter. That is clearly not the case in a drum of the spiral form, the rope that is being wound on the drum coiling on an ever-increasing diameter, and the one that is being unwound uncoiling from an ever-decreasing diameter. This, it will be seen in the present chapter, assists the engine, but spiral drums have certain disadvantages, as, for example, being very heavy and costly, and are therefore not always used. The following are some particulars in reference to an improved steel spiral drum winding from a depth of 763 yd.: weight of drum about 80 ton; width 15 ft. 9 in.; smaller diameter 18 ft.; larger diameter 33 ft.; net weight of coal raised each wind 4 tons; circumference of winding rope $5\frac{3}{4}$ in.

257. **Headgear and Pulleys.**—Other very common names for the erection supporting the pulleys are *pit-head frame* and *pulley frame.* Pit-head frames (fig. 185) usually consist of four uprights or legs, two back-stays, and certain cross-pieces. The two uprights, the tops of which are directly under the pulley-shaft bearings, are for carrying the load to be raised, the two in front of these to enable cross-beams to be fixed, and the two back-stays for preventing the frame from being drawn over in the direction of the engines. In addition to the cross-pieces already mentioned others are used for binding the various parts together and adding to the strength of the structure. Pit-head frames are subject to great strains, and require to be strongly built and to rest on secure foundations.

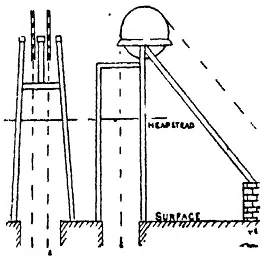


Fig 185.—Front and Side Views of Pulley Frame and Pulleys

They are constructed of wood, iron, or steel, and are sometimes as much as 80 ft. in height.

The *pulleys*, supported on cross-beams at the top of pit-head frame, change the direction of the ropes. The rims and centres are constructed of cast iron, and the spokes of wrought iron or steel. They are made very large to correspond with the size of the drum, but do not appear so viewed from the ground. Pulleys 18 and 20 ft. in diameter are common.

258. **Winding Ropes.**—Round ropes of steel wire are generally employed in this country. Iron-wire ropes are also used at some collieries. These are much heavier

than steel-wire ropes for equal strength. Flat ropes of steel wire have also been tried. Formerly flat ropes made of hemp were much used. The ordinary form of round rope consists of a number of strands twisted round a hemp core, each strand being made up of a certain number of wires.

Fig. 186.—Socket Capping

The manufacture of steel-wire ropes has reached a high degree of perfection. As a rule no winding rope is loaded beyond about one-tenth of its breaking load (one-sixth for haulage ropes), thus there is a large margin for safety. The ropes are examined every day and regularly oiled or greased. Wire ropes must not be bent round too sharp curves. At the start of a wind the strain on the rope is greatest, and sometimes special devices are adopted for lessening this.

Rope Cappings and Cage Chains.—The cage is connected to the rope by means of chains (termed the "cage chains" or "bridle chains"), and for the purpose of attaching the chains a metal *capping* (called also *socket* or *hose*) is fixed on to the end of the rope. Fig. 186 shows one form of capping. The cage chains, usually four or six in number, are connected to a large link which is secured to the capping by a bolt. Obviously great care must be taken in the capping (or hosing) of a rope, and in seeing that the cage chains are properly connected to it.

259. **The Cages.**—These are strongly constructed of iron or steel, the floors being sometimes formed of wood. They are made as light as possible (hence now usually constructed of steel), to avoid adding unnecessary weight to the load on the rope. In many cases the cages are very large, having as many as four or more decks, and

257. **Headgear and Pulleys.**—Other very common names for the erection supporting the pulleys are *pit-head frame* and *pulley frame*. Pit-head frames (fig. 185) usually consist of four uprights or legs, two back-stays, and certain cross-pieces. The two uprights, the tops of which are directly under the pulley-shaft bearings, are for carrying the load to be raised, the two in front of these to enable cross-beams to be fixed, and the two back-stays for preventing the frame from being drawn over in the direction of the engines. In addition to the cross-pieces already mentioned others are used for binding the various parts together and adding to the strength of the structure. Pit-head frames are subject to great strains, and require to be strongly built and to rest on secure foundations.

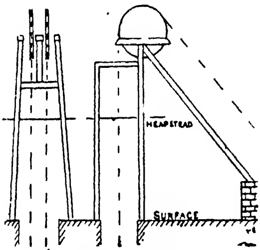


Fig 185.—Front and Side Views of Pulley Frame and Pulleys

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258. **Winding Ropes.**—Round ropes of steel wire are generally employed in this country. Iron-wire ropes are also used at some collieries. These are much heavier

in deep mines. Telephones are also used between the shaft bottom and the surface.

261. **Guides.**—Means require to be taken to prevent the cages, when travelling in the shaft, from coming in contact with each other or with the sides of the shaft or shaft fittings For this purpose *guides* (also called *slides* and *conductors*) are used. These extend from the surface to the pit bottom, and may be said to form two lines of "vertical railway" up and down which the cages run. Guides may be constructed of wood, or iron or steel rails, called *rigid* guides, or may consist of wire ropes, known as *flexible* guides.

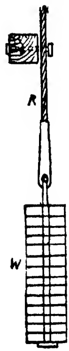


Fig 188.—Wire-rope Guides Arrangement at bottom of shaft for keeping guide tight

R, Rope; W, weights

Wood slides are used in rectangular shafts in Scotland. Long lengths of wood, 5 in. by 4 in. or other required dimensions, are fixed to buntons and joined evenly end to end (fig. 90). The cage is fitted with a *shoe* on each side where there is one guide on each side, or two shoes on each side where there are two guides; the shoe fits the slide loosely at the front and two sides.

Rail guides are also fixed to the buntons, the rails being joined end to end.

Wire-rope guides are suspended from the pit-head frame. At the shaft bottom they are secured to buntons, but in such a way as not to prevent them from lengthening or shortening (due to expansion and contraction); each is loaded to keep it tight (fig. 188). The shoe completely encircles the guide. This is the form of conductor usually employed in circular shafts. There may be two, three, or four ropes to each cage. Sometimes two additional ropes, termed "safety guides", are suspended in the space between the cages.

262. **Detaching Hooks and Safety Cages.**—Mention has already been made in the present chapter as to the use of safety appliances in the case of too rapid running near the end of the wind. *Detaching hooks* are for the double purpose of liberating the winding rope and suspending the cage, should the latter be drawn up too far at the surface, known as an *overwind*. They are not in use at every colliery.

The detaching hook (fig. 189, A) forms a link between the winding rope and cage, the winding rope in ordinary circumstances working through a cylinder or supporting ring fixed in the headgear, underneath the pulley. If an overwind takes place the detaching hook is drawn into the cylinder or ring; part comes in contact with this and the rope is set free, the hook at the same time catching on to the cylinder or supporting ring, and the cage thus remaining suspended (B, fig. 189). There are different makes of detaching hooks—*Omerod's*, *Walker's*, and *King and Humble's*.

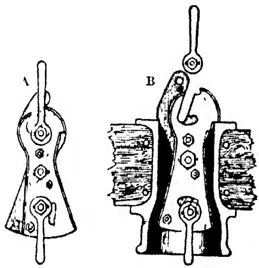


Fig 189 —Omerod Detaching Hook

Safety cages are cages fitted with appliances for gripping the guides and holding the cage in the event of the winding rope breaking. Owing to the difficulties in their use and the excellence of the winding ropes, combined with regular inspection and proper care, safety cages are not regarded favourably in this country.

263. **Counterbalancing the Weight of the Winding Rope.**—In some shafts a rope called a *tail rope* may be seen

attached to the bottom of each cage and working round a wheel or beam in the sump (fig. 190). This is for the purpose of counterbalancing the weight of the winding rope. During a wind the descending cage and tubs balance the ascending, and, if the winding rope is counterbalanced, the load against the engine at all parts of the wind is equal to the coal. This is often referred to as "equalizing the load on the engine", or "making the load uniform throughout the wind". Spiral drums also make the load uniform throughout the wind. There are other forms of counterbalance besides the tail rope and spiral drum.

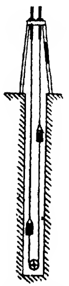


Fig. 190.—Tail-rope Counterbalance

Special Methods of Winding.—Various special methods of winding have been proposed. One of these, called the *Koepe system*, is to have only one winding rope and a large pulley with a single groove instead of a drum. The rope passes about half round the pulley, over the headgear pulleys, and each end is connected to a cage. A balance rope is used below the cages.

CHAPTER XXXIX

DEALING WITH THE COAL AT THE SURFACE

Weighing the Coal—Preparing the Coal for the Market—Surface Arrangements.

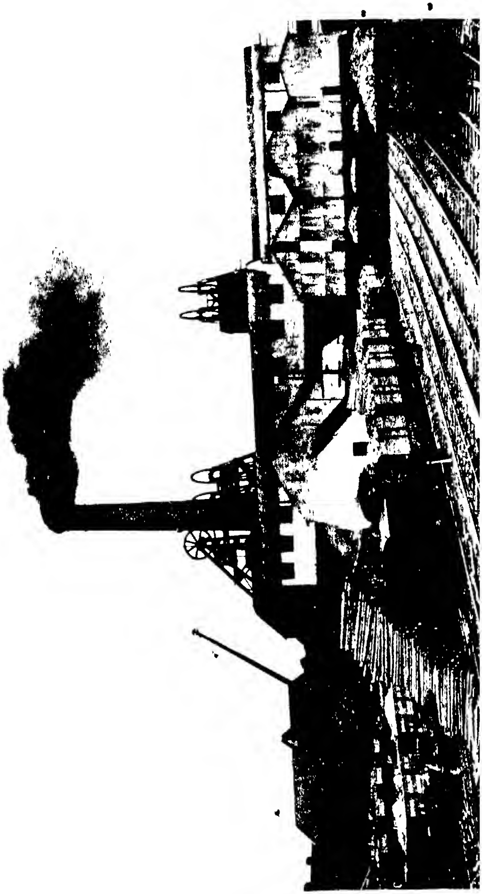
264. **Weighing the Coal. "Tallies" or "Pins".**—Dealing with the coal at the surface comprises changing the tubs on the cages (alluded to in the preceding chapter), weighing the coal, and preparing it for the market.

In weighing the coal, the full hutches pass on to the weighing machine on their way to be emptied. The weight of the loaded hutch is the *gross* weight, that of the empty the *tare*, and the difference the *net* weight, or weight of coal in each tub. The empty tubs are not weighed, the weight being known. The machine used may be of such construction as to indicate the net weight.

The weight of the coal in each hutch has to be ascertained in order that it may be credited to the person who has dug the coal, the coal-getters, as explained in chap. xviii, being usually paid according to the weight of coal produced by them. For the purpose of showing who has dug the coal, *tallies* or *pins* are used. These bear a distinguishing number (or are otherwise arranged so that no two coal-getters' tallies are alike), and each tub of coal which arrives at the surface having a tally attached to it, it is known at once who has sent the coal.

265. **Preparing the Coal for the Market.**—The preparation of the coal for the market means, of course, the treatment of the coal in such a way that it will meet the needs of consumers and thereby command a ready sale. It takes the form of dividing the coal into sizes and removing the rubbish, and is one of the most important branches of colliery work.

Methods of sizing and cleaning the coal, however, it should be observed, are of comparatively recent origin. In early times only the best seams were touched and the coal sent into the market as it came out of the mine. With the exhaustion of these seams the inferior beds had also to be worked (§ 50), and then it became necessary to adopt some special means whereby the condition of the coal might be improved. With the introduction of sorting and cleaning plants matters



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have gone on developing, and now we find at most collieries the most elaborate means for dressing the coal and sending it into the market in the best possible state.

266. **Surface Arrangements.**—In considering the coal cleaning and sizing arrangements we may glance at the surface erections generally. Standing over the pit-mouth is the headgear, and situated near by is the engine house containing the winding engines. Near to the winding-engine house are the *boilers* for generating the steam. A large number of boilers are required at an extensive colliery, and they are fired either by men or *mechanical stokers*. Means are provided for conveying the coal into the storage hoppers of the mechanical stokers, or to the heap whence it is shovelled into the hoppers or into the boiler fires where the stoking is done by men. The steam pipes which lead from the boilers to the engines are also to be seen.

Not far from the main winding shaft are perhaps other engine houses, containing the haulage, &c., engines, while near the upcast are the fan and fan engine working steadily on. Workshops and offices are also necessary, likewise railway sidings for the accommodation of the wagons for the transport of the coal, numbering perhaps as many as between 200 and 300 a day, and requiring the use of a shunting engine. At many collieries coke ovens are also in operation.

267. **The Pit-bank.**—Around the pit-top is the staging or floor on which the tubs are landed. This is known as the *pit-bank* or *pit-head* The operation of changing or landing the tubs is also known as "banking".

The pit-bank may be only a few feet above the level of the ground, according to the system of dealing with the coal, but is usually not less than about 20 ft. in height, to enable the coal to be passed easily from the landing place to the railway wagons below. It is

generally covered over, though formerly it was left unprotected, the work of banking, &c., having then to be done in the open.

Circulation of the Tubs on the Pit-head.—The loaded tubs pass from the cages to the *tipplers*, the appliances for emptying the tubs, the empties passing back to the pit-top to be again sent down into the mine.

It is important that the tubs should move on the pit-head with as little manual labour as possible, and so the rails are in some cases made to slope gently from the cages to the tipplers, the tubs running along this part by gravity. The line of rails for the empty tubs, from the tipplers back to the cages, is also made sloping for part of the way, and the empty tubs on leaving the tipplers run along this part also by gravity.

The tubs having thus been running downhill from the time of leaving the cages they will now be below the level of the landing-place, and must be taken up to that level. For this purpose a *hoist* is sometimes employed, but usually the tubs are drawn up an incline by an endless chain, called a *creeper chain*. This travels along between the rails close to the floor and has projections every few feet. One of these catches the axle of a tub and thus hauls the tub uphill. The top of the incline on which the creeper chain works is made high enough to enable the tubs to run down to the shaft by gravity. At the shaft there are *stop blocks* or *tub controllers* which hold the tubs and allow them to pass on to the cages as required.

Of course there are different methods of circulating the tubs. Frequently a creeper chain draws the full tubs up an incline from the shaft, the tubs then running to the tipplers, and the empties from the tipplers to the shaft, by gravity. Hand labour is also employed.

268. **Screening, Picking, and Washing Plant.**—The exact

method of dealing with the coal depends on the conditions, such as the amount of the impurities and the purposes for which the coal is intended, and therefore the arrangements vary at different collieries. We need glance only at the general process.

The tipplers (also called *tumblers* and *kick-ups*) have already been mentioned. There are different forms of tipplers. They require to empty the tub with the least possible breakage of coal, and at the same time act quickly.

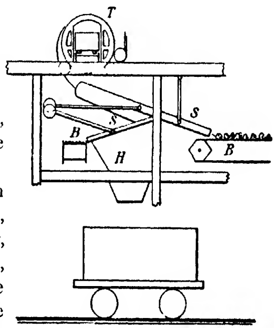

Fig 192 —Screening Arrangement

T, Tippler; S, S, shaking or jigging screens; H, hopper; B, travelling belts

The general plant, in addition to the tipplers, consists of the *screens*, *picking belts* or *bands*, and *coal washers*. The screens are for sizing the coal and are of different kinds. In the oldest form the bars on to which the coal is delivered are fixed. In improved forms movable bars are used. The commonest type of screen is, however, the *shaking* or *jigging screen*, this having a backward-and-forward motion. In the jigger screens perforated plates and wire netting are used as well as bars. The various sizes of coal produced in screening are "round coal", "cobbles", "nuts", &c., some sizes receiving different names in different districts.

The coal passes direct from the screens, or is delivered by other means, on to the *picking belts* or *bands*. These may be as much as 70 or more feet in length and about

4 or 4½ ft. in width. They are made of steel plates attached to endless chains, and travel forward slowly, passing round a drum at each end (fig. 192). The pickers stand along each side and remove the rubbish as the coal is carried along. The coal is delivered by the belts into some form of movable shoot by which it can be lowered into the wagons without breakage. Belts with perforated plates, or constructed of wire netting, are also used, these allowing small coal to pass through, while sometimes instead of belts *revolving picking tables* are employed.

For removing the rubbish from the small coal which falls through the screens or travelling belts picking is not suitable, and *coal-washing machines* (or "washers") have to be used. There are different kinds of these, but all depend for their action on the fact that the pieces of impure material are heavier bulk for bulk than coal. Hence in the washer, the material being agitated, the lighter coal becomes separated from the heavier rubbish. Pieces of coal and rubbish of different sizes may, however, weigh the same, and so the small coal is sized before it is washed, being lifted to the required point by *elevators*. Washing the coal is sometimes termed the *wet method* of cleaning.

CHAPTER XL

FREEING THE MINE OF WATER

Water entering the Mine—Underground Dams—Removing the Water from the Mine.

269. **Water entering the Mine.**—Water occurs in large or small amount in most mines, more, as a rule, being given off in shallow than in deep mines. In our geology

lessons we learnt how the water finds its way down through the rocks, and in chap. xx, how that which enters the shaft may be carried down in pipes to a lodgment or the sump. Again, in chap. xxv we saw how water may enter the mine from old workings. Water draining through the rocks may also pass into the mine at different parts of the workings. A continuous inflow at any part or into the shaft is termed a *feeder*. Some feeders are very large, amounting to thousands of gallons per hour.

270. **Dealing with the Water. Underground Dams.**—Now wherever it is possible (as may be the case in connection with old workings, but seldom at other places), and especially where the quantity is large, steps are taken to prevent the water from entering the mine, thus besides avoiding the trouble that its presence entails, saving the constant expense of pumping it to the surface, and perhaps also the cost of laying down pumping plant. When this can be done *dams* are employed, a dam, therefore, serving the purpose in a mine that water tubbing or coffering does in a shaft.

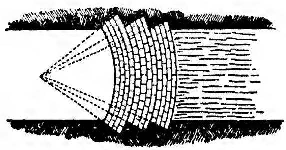

Fig. 193 - Plan of Masonry Dam

Dams for Heavy Pressures.—For resisting heavy pressures *wood* dams, built in the form of a wedge, or *brick* dams, constructed as shown in fig. 193, are employed. Concrete is also used in the construction of dams.

In fig. 193 three dams are shown, one in front of another. To allow of the water running off, and also the men passing through to the back, while the dam

is being constructed, a pipe is built in the masonry near the floor. This pipe is afterwards closed. Sometimes two pipes are used. Through another pipe of small diameter, near the roof, the air and gas behind the dam escape as the water rises upwards. Sometimes a valve is fitted to this pipe to permit of the water being drawn off at any time, and by means of a pressure gauge the pressure of the water can be ascertained.

Dams for Small Pressures.—Sometimes the pressure to be resisted is small, and then a *straight dam* (not wedge-shaped or curved) is sufficient. When clay is used as an aid in making the dam water-tight the term *clay dam* is sometimes employed.

Selecting and Preparing the Site of a Dam.—In selecting the site of a dam care is necessary. The ground must be strong enough to support the dam, and free from cracks or fissures through which the water might afterwards find its way. In preparing the site only picks and wedges are used, explosives fracturing the ground and rendering it liable to leak.

271. **Draining the Workings.**—Where water is given off in rise workings it runs downhill by gravity, and is guided to the shaft bottom or level, along which it flows to the sump. Sometimes in rise workings the conditions are such that a siphon can be used.

It is more difficult to deal with water in workings which dip away from the shaft bottom than in those which rise from it, the water having to be raised to the level or shaft bottom. Where the quantity is small, it is filled into and removed in tubs or tanks constructed for the purpose, or hand pumps are used. For larger quantities pumps worked by water power (called *hydraulic pumps*), compressed air, or electricity are employed. Pumps driven by other means are also

in use. Siphons are utilized in dip workings where the conditions are suitable.

272. Removing the Water from the Mine.—In some cases *adit levels* (fig. 194) can be used for this purpose, but generally *pumps* have to be employed. Sometimes, where the quantity of water is small, it is raised in tanks by the winding engine.

Where pumps are in use they are generally worked by a steam engine, placed either on the surface or underground. With the engine on the surface pump-rods must pass down the shaft. These are usually of wood, consisting of long lengths joined together by plates and bolts. Wooden rods may be as much as 12 or 14 in. square. Iron and steel rods are also used.

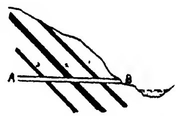

Fig 194.—Drainage by Adit Level The adit level, A B, drains the strata above, including the coal seams 1, 2, 3

Rods which work inside the delivery pipes (§ 223) are termed *wet rods*, and those which work openly in the shaft *dry rods*. To steady the latter and keep them from bending, *guides* (or "collarings") are fixed in the shaft, and to prevent the rods from being worn away by rubbing against the guides *wearing pieces* are fixed to them. *Catch pieces* are also attached to the rods, these catching on to beams (called *banging beams*) fixed in the shaft and holding the rods in the event of breakage. Usually the pump-rods have to be counter-balanced. The pipes require to be carefully supported in the shaft.

Where the depth from the surface to the point from which the water has to be conveyed is not great the pump (or pumps, if more than one) may lift or force (according to the kind of pump) its water direct to the surface, but where the vertical distance is considerable this is not possible and the water has then to be raised

in stages, one pump conveying it to another placed farther up the shaft, and this second pump raising it to the surface or to a pump still higher up. The pumps thus work in *sets*, the distance that any one of them raises the water being called a *lift*. The lift for a plunger pump (or *forcing set*) is longer than for a bucket pump (or *lifting set*). Generally in an arrangement such as this a bucket pump is used for the bottom lift and forcing sets for those higher up. Main rods pass down the shaft and the pumps are connected to these by *off-sets*.

With the engine underground force pumps only are used and there are no rods in the shaft. Steam pipes are, however, necessary for conveying the steam to the engine, though electrically-driven pumps are also used. The length of lift is longer than in the case of pumps with rods. Pumps with the engine underground are known as *direct-acting pumps*.

A certain amount of standage (§136) is provided for the water in case of a stoppage of the pumps, and where the water is corrosive means have to be taken to protect the pumps from its injurious action.

CHAPTER XLI

MISCELLANEOUS

Electricity—Surveying—Accidents—Rescue Appliances—Ambulance Work—Ankylostomiasis—Baths

273. **Electricity.**—Reference has been made frequently to the use of electricity in mines, and we have seen that it is employed for many purposes, being applied in lighting, shot-firing, coal-cutting, hauling, winding, &c. Now,

it must be observed that electricity is not a *primary* source of power, just as steam is not. Steam, it has been shown (§ 183), derives its energy, or power of doing work, from the coal burnt in the boiler furnace, and similarly electricity derives its energy also from coal or from some other source.

We can produce electricity by friction. Thus, if we warm a glass rod and then rub it with a piece of warm, dry silk, we find it will attract light substances, as fragments of paper, pieces of cut straw, &c. Electricity has, in fact, been developed on the surface of the rod, or the rod has become, as we say, "electrified" or "charged". It was known 2500 years ago that amber, when rubbed, acted similarly to the glass rod, hence our word "electricity" (Gr. *elektron*, amber).

274. **Current Electricity.**—In the case of the rubbed glass rod the electricity resides on the surface of the rod, but as used in a mine the electricity, as we have already learnt, flows along a wire or a cable, and comes under the general term *current electricity*. The flow of the electricity has been compared to that of a current of heat along a conductor (§ 182). The two ends of the wire or cable are at different "electric potentials", and the current of electricity flows from the higher potential to the lower, just as, when the two ends of a conductor are kept at different temperatures, heat flows from the higher to the lower temperature. In both cases we cannot see anything passing or "flowing" along; the conductor, however, exhibits different properties or effects.

For small quantities, such as are required in signalling operations, the current of electricity is produced by chemical action in a *cell* or *battery*, a battery consisting of two or more cells connected together. Where, however, the amount of current is large, as in electric lighting, hauling, &c. a machine, called a *dynamo* or

generator, worked by a steam engine or water power, &c., has to be used.

275. **The Simple Cell.**—We put into a glass vessel (fig. 195) some water, add a little sulphuric acid, and then immerse in the acidulated water a strip of copper, C, and another of pure or amalgamated zinc, Z. On bringing the strips into contact, or connecting them by twisting together the free ends of copper wires attached to the top of each, chemical action takes place and a current of electricity flows as shown by the arrows. If

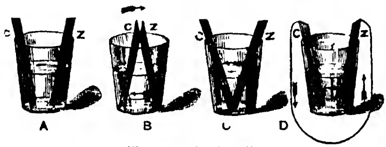

Fig 195 Simple Cells

Copper and zinc in liquid—A, No action, B, current across liquid and from C to Z; C, current across liquid and through the touching ends from C to Z D, current across liquid and through wire.

we connect the ends of the wires to an electric bell, instead of to each other, the bell rings, proving that a current of electricity is passing. Instead of the electric bell we may employ other means to show that a current of electricity is travelling along the wire (§ 278).

The arrangement just described (D, fig. 195) is called a *simple cell*, or *voltaic cell*, after Volta, by whom it was discovered. From the figure we see the current flows from C along the wire to Z, and from Z through the liquid to C. This is termed the *circuit*. When the wires are connected, we say the circuit is "closed"; when they are unconnected, we say the circuit is "open" or "broken". No flow of current takes place unless the circuit is closed. Thus, if we are using an electric bell to show that the current is passing along the wire,

the bell does not ring if only one wire is connected to it; or if we have both wires attached to the bell, until we close the circuit by means of the "push", or as in signalling (§ 253). The copper and zinc plates are termed the *poles* of the cell, the copper being the *positive* pole and the zinc the *negative* pole.

In chap. xxix we learnt as to the preparation of hydrogen. When the circuit is closed the zinc is eaten away and the sulphuric acid used up, with the formation of zinc sulphate and hydrogen. The consumption of the zinc furnishes the energy by which the current is driven through the circuit.

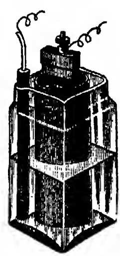

Fig 196.—Leclanché Cell

276. **Other Cells.**—When the simple cell is working it is found that a layer of hydrogen bubbles forms on the copper plate. This, termed *polarization*, diminishes the flow of electricity, and may stop it altogether. Other forms of cells have therefore to be used, as the *Daniell* and *Leclanché*. The latter (fig. 196) is the one employed for signalling in mines. The positive pole is a rod of carbon and the negative pole one of zinc. The carbon rod is contained in a porous pot, the space round it being packed with small pieces of carbon and black oxide of manganese. A terminal screw is fixed to the top of the carbon rod. The porous pot and zinc rod are placed in a solution of sal ammoniac (ammonium chloride, NH_4Cl) contained in a glass vessel. The hydrogen which is liberated in the chemical action in trying to reach the carbon rod is oxidized by the oxide of manganese. The oxidation proceeds slowly, therefore this cell is not suitable for constant working, but is very convenient where it can be given "rests", as in signalling.

Batteries.—All that can be said here is that a battery is, of course, more powerful in its effects than a single cell, and that the cells may be arranged in *series*, in *parallel*, or a combination of these.

277. **Conductors and Insulators.**—We must distinguish clearly between these. If we rub a brass rod, held in the hand, with a piece of warm silk, we find it is impossible to electrify it as we did the glass rod. This is because the electricity passes along the rod and escapes by the hand holding the latter, passing or being conducted to the earth through the person's body. If now we fit the brass rod with a glass handle, or wrap a sheet of gutta percha or indiarubber round the end we grasp, the electricity can no longer escape, and the rod becomes electrified. Bodies, then, which, like brass, present little resistance to the flow of the current, are termed *conductors*, while bodies such as glass, gutta percha, indiarubber, &c., which offer great resistance, are called *non-conductors* or *insulators*. (See also § 253 as to use of insulators; the wires must be supported on insulators to prevent the escape of the current and "short-circuiting").

In electrifying a substance by friction the rubber also (as well as the substance rubbed) becomes electrified, if proper precautions are taken to prevent the escape of the electricity. The human body, it must be observed, is a good conductor of electricity.

278. **Effects of Current.**—As already referred to, and as we have seen in some instances, a current of electricity flowing in a circuit produces various effects, as (1) heating the wire if it presents much resistance to the passage of the current (§ 205); (2) producing light if the current is powerful enough (§ 242); (3) decomposing certain compounds, as water (§ 193); (4) deflecting a magnetic needle; (5) converting a bar of iron into a

magnet, called an *electromagnet*, if the wire, insulated, be coiled round the rod (fig. 197); (6) producing a shock if the free ends of the wires from the battery be touched simultaneously, and the latter be sufficiently powerful. Here the person's body forms part of the circuit.

279. **Dynamo, Motor, &c.**—The main parts of an electrical installation at a colliery are: (1) the *generating plant* at the surface, consisting of dynamo and driving engine; (2) the *cables* along which the current flows, these being led down the shaft and along the drift; and (3) the *electric motors* which work the underground machinery. Besides these there are *switches* for switching on or off the current, and other necessary appliances. There are now in force, under the Coal Mines Regulation Act, special rules for the installation and use of electricity in mines, and much can be learnt from a consideration of these. The young reader must, at least, note such of the rules as directly concern him.

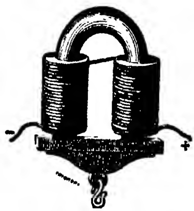

Fig. 197. Horseshoe Electro-magnet

Very little more can be said here regarding this extremely interesting subject, electricity. It has been mentioned how a magnet may be produced by an electric current. Conversely, magnets can produce electric currents, and forming part of every dynamo there is a magnet called the *field-magnet*, and another appliance termed the *armature*. One or other of these is made to revolve, according to the make of the dynamo, and the result is that the mechanical power of the driving machine is converted into electrical power and the current passes into the cable. In the mine, or place where the work is to be done, the electric motor, similar in con-

struction to the dynamo, converts the electrical power into mechanical power to work a pump, haulage engine, &c. (fig. 198). Thus the power of the driving engine on the surface can be conveniently transmitted to wherever required.

280. **Surveying.**—Surveying is defined by an early writer as "the art of ascertaining, by measurement, the shape and size of any portion of the earth's surface, and representing the same, on a reduced scale, in a conventional manner, so as to bring the whole under the eye

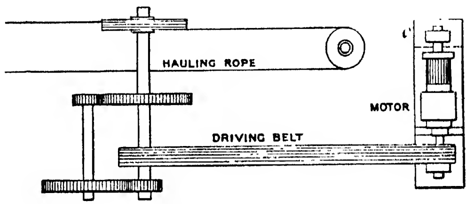

Fig. 198.—Electric Haulage

at once". There are different branches of surveying, involving special training and skill on the part of those who practise them, and *mine surveying* is one of these. The work of the mine surveyor can be understood to be of great importance and to require the utmost care in its performance.

The surveyor makes a large drawing, or *plan*, on which he shows the position of the workings with regard to the surface, and in which, therefore, can be viewed the various roads, goaves, &c., all in their proper positions, just as the streets, parks, &c., can be seen in the plan of a town. The keeping of this plan is made compulsory by the Coal Mines Regulation Act. It is drawn to a certain scale, and must show the workings up to a date

not more than three months previously. When any mine or seam is abandoned, either the plan itself or an accurate copy of it must be sent to the Secretary of State.

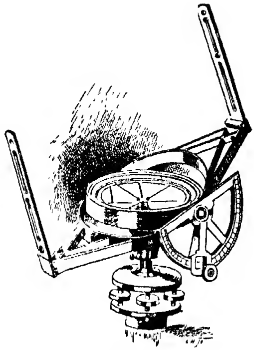
Fig. 199 —Miner's Dial

The chief instruments used by the mine surveyor are the *miner's dial* or *compass* (also sometimes termed *circumferenter*), *theodolite*, *dumpy level* with *levelling staff*, and *chain*. Each of the two first-named (figs. 199–200) is provided with a magnetic needle, one end of which, when the needle settles in a horizontal position and there is no substance, as iron, to deflect it, always points to the *magnetic north* (not the *true* or *geographical* north). By this property of the needle the surveyor is able to tell the position of the workings with regard to the surface and obtain information necessary for the making of his plan.

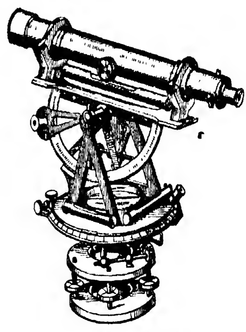
Fig. 200 —Theodolite

By means of the *dumpy level* (fig. 201) and *staff* the difference of level between any two places in the mine can be ascertained, the

particulars thus obtained enabling the manager to tell how much cutting or banking is necessary to make a road of uniform gradient, whether it is possible to use a siphon in a particular place, &c.

The chain is for measuring distances. It is sometimes termed *Gunter's chain* after Edmund Gunter, who invented it in 1620. It is 4 poles (therefore sometimes termed the "four-pole chain") or 22 yd. in length, and accordingly there are 80 chain lengths in a mile, 10 sq. chains in an acre, and 6400 sq. chains in a square mile. It is made up of 100 links, therefore each link measures 7·92 in., and there are 100,000 sq. links in an acre. The length of the chain and number of links thus, it will be seen, afford facility in calculating areas, this being the reason why the inventor chose the particular length and number of links. For surface measurements a chain 100 ft. in length, called the "100-ft. chain", is sometimes used.

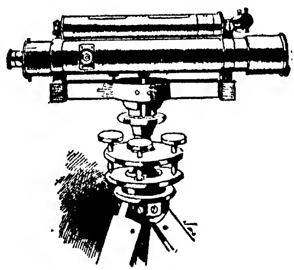

Fig 201.—Dumpy Level

281. **Accidents.**—The special rules (§ 279) indicate the means that must be adopted to prevent fires and injury to workmen from the use of electricity in mines. But shocks are sometimes received by persons carelessly, or through ignorance of the danger, coming in contact with cables or parts of the electrical machinery. If a shock is severe enough fatal results ensue. Care must be taken to protect horses. A horse has been known to bite through the insulation of a cable and receive a shock

which killed it. A person going to the assistance of anyone (or of a horse) who has received a shock must guard against receiving a shock himself.

In regard to accidents in general much has been done to reduce the proportion of these, and with the adoption of improved methods which result with the passage of time, faithful observance of rules, and care, such as has been already indicated, much doubtless will yet be done. Miners should clearly understand that the rules have been framed for their safety; and a miners' representative in Parliament, addressing miners in regard to the importance of learning and obeying the rules, said: "No man has the right to take his own life, much less endanger the lives of others. Let it be recognized among you that no man known to be careless in the observance of the law is worthy to work in the mines."

282. **Rescue Appliances.**—Within the past few years attention has been drawn to the use of breathing appliances in mines, designed to enable a person to explore a mine after an explosion, or assist in extinguishing an underground fire, without incurring the risk of breathing the poisoned atmosphere. There are different types of breathing appliances. In one the exhaled air passes into a bag (front, fig. 202), where the carbonic gas and moisture, which we know are given off by all persons, are absorbed. Forming part of the apparatus are cylinders containing a store of highly compressed oxygen (back, fig. 202), and the necessary quantity of this gas mixes with the air, which has been freed from the carbonic acid gas, before it is again inhaled. The nitrogen is thus inhaled over and over again, but the supply of oxygen becomes gradually exhausted.

It will be evident that great care and skill are necessary in the use of such appliances, and it has been

proposed that rescue stations should be fitted up in central places where men would be specially trained. This has been done in some cases.

Fig. 202.—The "Pneumatophore" Rescue Appliance

283. **Ambulance Work.**—This means, in short, the ability to render "first aid" to any injured person, persons suffering from electric shock, or from the inhalation of noxious gases. It is evident that such knowledge must prove very valuable in many cases,

and all young miners should therefore acquire it. By the Coal Mines Regulation Act ambulances or stretchers, with splints and bandages, must be kept ready for immediate use at all mines (G.R. 34), and instructions as to the restoration of persons suffering from electric shock are required to be posted up in every generating, transforming, and motor house.

284. **Ankylostomiasis.**—Another name for this disease is "miner's anæmia'. It is due to a species of worm, sometimes termed the "miner's worm" which lodges in the upper part of the small intestine. The eggs produced there by the female worm are deposited in the fæces of the infected person, leading to the infection of other persons. The disease is common among the miners of some foreign countries (it is said to have been practically stamped out in Germany, but at enormous cost), and is known to have existed in Cornwall. Certain conditions of warmth and moisture are favourable to the hatching of the eggs and development of the larvæ, and these conditions do not exist in all mines. No case of infection has been discovered in the coal mines of Britain.

To stop the spread of the disease, or prevent risk of infection, the pollution of the ground in mines has to be avoided, The management of the mine will decide what sanitary precautions are necessary, but, whatever these are, miners for their own sake must carefully observe them.

285. **Baths.**—At some collieries at home, and many abroad, arrangements are made whereby the miner washes or bathes himself on ascending to the pit-bank. He leaves his pit clothes at the pit, where they are dried, if wet. He thus proceeds to and from the pit in clean, dry clothing, This adds greatly to the comfort of the miner, and makes his home life more pleasant.

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